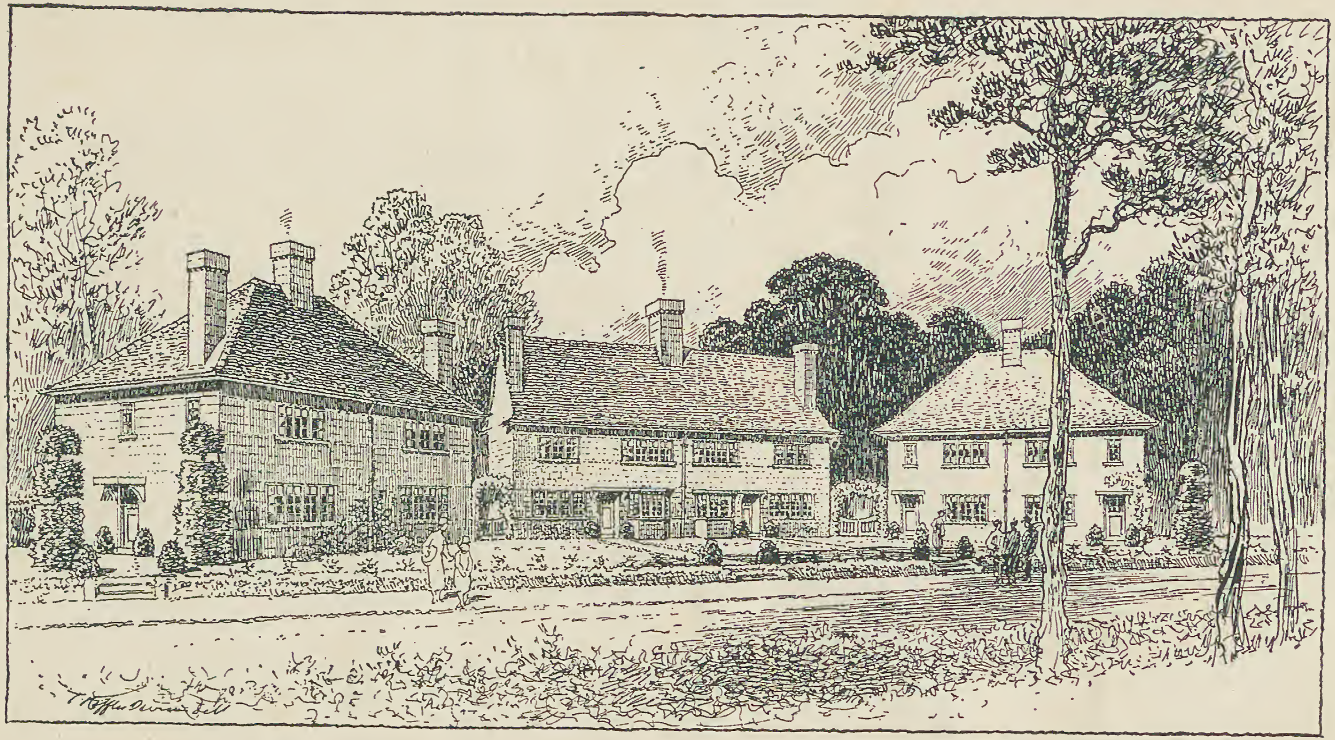
CONCRETE HOUSES AND SMALL GARAGES



[T. Raffles Davison, Hon. A.R.I.B.A., delt.

SUGGESTED GROUPING OF SOME OF THE TYPES OF HOUSES DESCRIBED IN CHAPTER III.

CONCRETE HOUSES
AND SMALL GARAGES

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PREFACE

Although the title of this book has been changed from " Concrete Cottages, Bungalows, and Garages " to " Concrete Houses and Small Garages," the contents are substantially the same. This is because the older and well-tried methods are still the most suitable for the single houses or small groups of houses which account for by far the largest proportion of the houses built. Some of the newer systems, which can generally be used only with the consent of the proprietors of the systems, who may also undertake the work of erection which often requires the use of expensive plant, are more suitable for large groups of houses, and experience has shown that houses built on special systems since the year 1945 have cost more than brick houses of the same size. The greatest economy in concrete work results when a supply of suitable aggregate is available near the site so that transport charges are low, and when local semi-skilled labour can be used.

The text has been revised to accord with modern practice, but no attempt has been made to follow any particular by-laws, codes, or standards. The book describes sound practice which can be generally applied with any modifications necessary to meet local requirements. Plans acceptable to the Ministry of Health for the grant of subsidies in the case of houses built by local authorities in Britain are given in the " Housing Manual," published by H.M. Stationery Office. No attempt is made here to give designs for the construction of these particular types, but rather to give sufficient information to enable the reader to conform to any plan.

The methods of construction are affected to some extent by the plan, and this should not be overlooked when efforts are being made to produce economical buildings ; for example, if the floors and roof are of concrete the plan must permit the use of economical spans for the beams and slabs. The best plan is that which is the most simple and compact ; novel types are invariably more expensive than a straightforward arrangement.

Concrete houses should be designed with the possibilities of the material always in view. If precast concrete is used the walls and their openings should be arranged so that standard size blocks or slabs may be used without the need for using odd sizes. If monolithic construction is adopted, the walls should be designed so that the shuttering may be as simple as possible and used repeatedly ; to this end it is desirable on a large scheme to use as few different elevations as possible and to rely more upon grouping for architectural effect. Methods of achieving this relationship of design and materials with a view to economical building without loss of architectural appearance are suggested in this book.

A great deal of experience is now available on the durability of some of the different types of concrete houses built in the early 1920's ; this is described in

the report of a committee appointed by the Ministry of Works, the Ministry of Health, and the Department of Health for Scotland and published by H.M. Stationery Office in 1945 as " Post-War Building Studies No. 1, House Construction." The committee, under the chairmanship of Sir George Burt, made a thorough inspection of some of the principal methods of constructing concrete walls for nearly 30,000 houses. It is shown that, generally, concrete walls are no cheaper than brickwork and that they are no quicker to build, but that they are as strong and durable as brickwork, cost no more for maintenance, and give as comfortable a house. In the absence of any other convenient standard, the committee has made all its comparisons with an 11-in. cavity brick wall. (A summary of this report is given in Appendix I.)

No restriction is placed on the use of the designs and details prepared by the writer and given in Chapters II to IV.

1949. A. L.

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CHAPTER I

CONCRETE

Materials.

Good concrete can be made with materials the bulk of which is generally obtainable near the site. Clean and strong coarse aggregate, clean sand, and good Portland cement are necessary for making good concrete, and these materials should be mixed in the proportions which will produce a concrete having the necessary strength and other properties combined with the greatest economy. Good results cannot be obtained if care is not taken in the selection of materials and the mixing, placing, and curing of the concrete. The principles of making concrete are well known, and it is not proposed here to deal at length with the subject except insofar as the special requirements of house building are concerned.

Aggregates.—In selecting the coarse material the products of the locality of the site should be investigated, and the best of these used if suitable material cannot be obtained on the site. The expense of conveying aggregates from a distance increases the cost of the work, and it is not often necessary. In some districts ballast is available, in others crushed stone ; when both are readily obtainable the merits and cost of both should be considered.

Cleanliness.—Clean aggregates are essential. Dirty aggregates are those containing loam, clay, and organic matter. The value of cement lies in its property of combining aggregates together by its adherence to each grain of sand or piece of stone, and if the sand or stone is already coated with loam or clay the strength of the concrete will depend upon the adhesion between the sand or stone and the covering layer of clay or loam. A dirty aggregate can sometimes be detected by rubbing some of it between the hands and observing the staining effect, but a better test is to stir a handful of it in a glass jar with water, when the loam or clay will, on settling, form a layer by itself. Dirty aggregates should be washed, but it is generally cheaper to buy clean material than to install a washing plant and treat a dirty but cheap material.

Sand or gravel containing organic matter (vegetable debris or animal refuse) is particularly objectionable, but there is a simple test for organic matter in sand which can be applied without difficulty. The test is conducted by shaking some of the sand in a plain glass bottle with a 3 per cent. solution of caustic soda and allowing the mixture to stand for 24 hours. The amount of caustic soda solution used should be such that it is about equal to the bulk of the sand. If after standing for 24 hours the colour of the solution is no more than a pale yellow the sand is satisfactory, but if the colour is a marked yellow or brown the presence of organic matter is indicated.

Artificial Aggregates.—Artificial aggregates, such as broken brick, clinker,

etc., must be free from lime or partly-consumed coal, otherwise there is a risk of the concrete expanding after it has set. Coke breeze is largely used as an aggregate with satisfactory results where no great strength is required, but it is essential that it should contain no coal. Breeze or clinker should not be used in reinforced concrete work, chiefly because of the possibility of moisture percolating through and rusting the steel. With old broken brick there is the risk of lime being included from adhering mortar, or sulphate of lime from rapid-hardening plaster, so that bricks are not safe to use as an aggregate unless they have been well cleaned. Certain classes of brick made from clay containing pyrites are liable to contain sulphur in an active form and concrete containing such broken brick is liable to swell after setting, especially if it is in a damp situation.

The aggregates marked with an asterisk in the list on page 4 are porous, and all porous aggregates (including some varieties of stone) should be well soaked with water before use; otherwise they will absorb from the concrete the water required for the setting action of the cement, thus causing imperfect hardening and cracking of the concrete. Some porous aggregates are slow in absorbing water, and it is best to soak them the day before use and again immediately before use.

Size of Aggregate.—The size of the aggregate will depend upon the nature of the work. For monolithic walls 6 in. thick the coarse aggregate should not exceed 1 in., while for precast slabs not exceeding 3 in. thick aggregate not larger than $\frac{1}{2}$ in. should be used if a good surface is to result from the common methods of manufacture. When monolithic walls are built the ramming and spading of the concrete as it is placed in the shuttering cause fine material and cement to flush against the shuttering and form a smooth face to the wall. If precast slabs are made in a machine and the concrete is rammed into position, the face of the slab is generally at the bottom of the mould so that spading is impossible. The use of smaller aggregate under these conditions allows the particles of different sizes to slip into place under pressure of ramming only, and thus produce a smoother face. A maximum size of $\frac{1}{2}$ in. should be used for precast slabs, while $\frac{3}{8}$-in. or $\frac{1}{4}$-in. material gives a still smoother surface.

Grading.—The fine aggregate or sand should be considered as including all particles smaller than $\frac{3}{16}$ in. The sand should have grains of varying sizes. Very fine sand is undesirable, as it is liable to contain a large quantity of fine particles of loam or dust, and it will need a greater proportion of cement if the concrete is to have the same strength as concrete made with larger and better graded material. The best sand to use is that which is graded from $\frac{3}{16}$ in. down to fine particles.

The grading of aggregate, by which is meant the selection of the sizes of the pieces and grains of which it is comprised, is important. When fine or dusty aggregate is used additional water is required for mixing, and in consequence the concrete is weakened. For the best results the proportion of dust should not exceed 10 per cent. as ascertained by sifting the material on a British Standard sieve No. 100, which has meshes 0·006 in. square. The proportion of cement-and-sand mortar should be at least sufficient to fill the voids between the stones. The most economical concrete will be that which has the least voids in both sand and stone. Sources of aggregate are rarely found in which the materials

are already in the best proportions, so that to obtain maximum density it may be necessary to separate the aggregates into different sizes and mix them again in the proportions found to produce the densest mass. If the aggregate has too much or too little sand it should be passed over a sieve with openings of $\frac{3}{16}$ in. so as to remove the larger material, and the material retained on the sieve should be then passed over a sieve with openings corresponding to the maximum size required so as to remove the oversize material.

CEMENT.—Three classes of cement are available for use in concrete, namely ordinary Portland cement, rapid-hardening Portland cement, and high-alumina cement.

Rapid-hardening Portland cement attains its strength at an earlier age than ordinary Portland cement and economies are possible due to its early hardening properties. These savings may exceed the slightly higher price of the cement. For example, under ordinary conditions rapid-hardening Portland cement enables shuttering to be stripped from walls two days after the concrete is placed and used again in another position, while some precast products can be taken from their pallets after 24 hours and built into the house seven days instead of 28 days after they are made if ordinary Portland cement is used.

High-alumina cement concrete one day old has the strength of a fully-matured concrete made with ordinary cement, but due to its high cost it is not used for house building.

White Portland cement costs more than three times as much as ordinary Portland cement, and is used as a facing only for in-situ or precast concrete. It is also necessary to use white Portland cement for the lighter shades of coloured concretes and mortars. The introduction of colouring matters into concrete has been practised for some years, and it is now possible to obtain cements of several colours and shades, as described in Chapter VIII.

WATER.—Water used in making concrete must be clean. Where ordinary drinking water is not available the water must not be contaminated. One of the causes of weak concrete when the mixture and materials are apparently correct is the use of too much water; the least water used the better the concrete will be, so long as sufficient water is present to hydrate the cement and provide a workable concrete.

Proportions of Materials.

Suitable proportions for concrete for houses cast-in-situ are 1 part of Portland cement, 2 parts of sand, and 4 parts of coarse aggregate. For unreinforced foundations and footings a leaner concrete, say, 1 : 3 : 6, may be used. For special facing concrete the mixture should not be leaner than 1 : $1\frac{1}{4}$: $2\frac{1}{2}$. For precast products of ordinary concrete with gravel or crushed stone aggregate a mixture of 1 : $1\frac{1}{2}$: 3 is commonly used, and this richer concrete is essential if the maximum size of the coarse aggregate is $\frac{1}{2}$ in. or less. In exceptional cases, and in all cases where there is a large amount of repetition using the same aggregates, the proportions which give the densest workable concrete should be determined by trial.

The cement should be measured by weight, thereby avoiding the uncertainties of measurement by volume. For this purpose it is generally assumed that 1 cu. ft. of cement weighs 90 lb., but it is better to use whole bags containing 1 cwt. of cement in a batch. The fine and coarse aggregate can be measured

by volume in boxes, but allowance must be made for the bulking of the sand due to moisture. Damp sand shrinks about 20 per cent. when it is saturated; 1 cwt. of cement equals $1\frac{1}{4}$ cu. ft. Thus a mixture specified as 1 : 2 : 4 is obtained by mixing together 1 cwt. of Portland cement, 3 cu. ft. of sand (measured when damp), and 5 cu. ft. of coarse aggregate.

Properties of Concrete.

WEIGHT.—Concrete is sometimes considered to be disadvantageous for houses on account of its weight. The density of ordinary Portland cement concrete is about 140 lb. per cubic foot, which is nearly 20 per cent. more than the weight of brickwork and about four times the weight of wood. The weight of concrete varies, however, according to the proportion of cement and the density and grading of the aggregates. Lean concrete, with the same aggregates, weighs slightly more than concrete richer in cement. Some limestones and brick produce concrete of lower density than gravel or shingle, and granite produces concrete of higher density. Reinforced concrete is heavier than plain concrete. For ordinary calculations the weight of reinforced concrete is conveniently assumed to be 144 lb. per cubic foot, that is, a piece of concrete 1 ft. long weighs 1 lb. for every square inch of cross-sectional area, or the weight in pounds of 1 sq. ft. of concrete slab is twelve times the thickness of the slab in inches.

LIGHTWEIGHT CONCRETE.—Lightweight concrete can be made with breeze, pumice, or foamed-slag aggregate. Where it is obtainable at a satisfactory price, foamed-slag is generally used because it is free from the risk of expansion to which breeze is liable unless the breeze is carefully selected. Foamed-slag is a by-product of blastfurnaces and the farther the site is from a blastfurnace the more expensive the material becomes.

"No-fines" concrete is a gravel concrete of low density obtained by screening out all the particles larger than $\frac{3}{4}$ in. and smaller than $\frac{3}{8}$ in., so that there is no fine material to fill the voids in a concrete made with aggregate of $\frac{3}{8}$ in. minimum size. Notes on the use of no-fines and other lightweight concretes are given in Chapter IV.

The average densities of the concretes generally used in the construction of houses are given in the following, for concrete mixed in the proportions of 1 part of Portland cement, 2 parts of fine aggregate, and 4 parts of coarse aggregate.

Type of aggregate	Weight (lb. per cu. ft.)
Ballast	140
Hard crushed limestone	135
*Broken common brick	125
*Clinker	110
*Coke breeze	100
*Foamed slag	85
*Pumice	50

* Porous aggregates.

The weights of concretes made with some of these aggregates are given in *Table* I.

Another lightweight concrete is cellular concrete which is generally made by adding to the cement a proportion of powdered aluminium or zinc. In combination with the lime in the cement and the mixing water, these powders change respectively to calcium-aluminate and calcium-zincate, which develop hydrogen and increase the volume of the concrete. By controlling the proportion of the

powder, cellular concrete can be made weighing as little as 40 lb. per cubic foot. This concrete has not, so far as the writer knows, been used for in-situ houses in this country, probably due to the difficulty of controlling the expansion on the site. Cellular concrete is also made by entrapping air in the mixture.

Strength of Concrete.—The strength of concrete increases as the weight increases. With a particular aggregate the densest concrete is the strongest. Only concrete made with crushed stone, gravel, or hard broken brick is strong enough for structural purposes and such concretes generally have a compressive strength of more than 2000 lb. per square inch at 28 days if made with ordinary Portland cement or at seven days if made with rapid-hardening Portland cement. With concrete rich in cement and with carefully selected aggregates and controlled quantities of water, strengths of more than 8000 lb. per square inch are not uncommon. The strength increases slightly between one month and one year. For cast-in-situ concrete mixed in the nominal volumetric proportions of 1 : 2 : 4, as might be used in house construction, a strength of 2250 lb. per square inch at 28 days is the lowest that should be used. For concrete made at a precast products works and mixed in the proportions of 1 : $1\frac{1}{2}$: 3, the strength at seven days, using rapid-hardening Portland cement, should be not less than 3300 lb. per square inch.

Lightweight concretes have low strengths and are not used for the purposes of load carrying.

Durability.—Resistance to weather is an important requirement for concrete used in exposed positions such as in the external walls of houses. One cause of disintegration of the surface of concrete is freezing of water in the surface pores. A concrete with a dense surface is generally more durable, since little moisture can be absorbed, but the density of the interior of the wall should not be greatly different from that of the surface otherwise the internal strains due to shrinking and changes of temperature, and volumetric changes due to moisture movement, may cause cracking of the surface.

A durable surface is obtained only if, in addition to the precautions necessary during making the concrete, the concrete is thoroughly consolidated when placed in the shuttering or moulds, and if it is properly cured by being kept moist for several days after casting.

Resistance to Fire.—Concrete has a high resistance to fire compared with many other materials used in the construction of houses. The fire resistance depends on the aggregate. Foamed slag and pumice make the most highly resistant concrete. Broken brick and other burnt-clay products, blastfurnace slag, well-burnt clinker, and hard limestone, are almost as good. The foregoing materials are classified by the Ministry of Works as aggregates in group 1. Aggregates that are classified as group 2 make concrete which, although generally of greater strength, is less fire-resistant than do aggregates in group 1. The materials in group 2 include all natural stones (except hard limestone which is in group 1) and gravels.

The resistance to fire necessary for a dwelling house is much below that required for other buildings, and structural and other requirements generally result in thicknesses of concrete walls, floors, and roofs in excess of the thicknesses required for adequate resistance to fire. The minimum thicknesses, exclusive of plaster, recommended by the Ministry of Works to give the resistance to fire

necessary for houses are given in the following. The resistance to fire of party walls is generally required to be much greater than for external walls and the thicknesses in brackets in the following are to the minima for party walls.

Concrete Bricks.—Solid wall with or without plaster, $4\frac{1}{4}$ in. ($4\frac{1}{4}$ in.). (Walls of concrete bricks are considered as having the same resistance to fire as a wall of common bricks of equal thickness. A cavity wall of concrete bricks has a resistance to fire far in excess of the recommended standard.)

Solid Concrete Blocks.—Solid wall without plaster: Aggregates in group 1, $2\frac{1}{2}$ in. (3 in.); aggregates in group 2, 3 in. (4 in.). Solid wall with plaster on both faces: Aggregates in group 1 or 2, 2 in. ($2\frac{1}{2}$ in. for aggregates in group 1; 3 in. for aggregates in group 2).

Hollow Concrete Blocks.—Wall plastered on both faces and with one cell in the thickness of the wall: Aggregates in group 1, $2\frac{1}{2}$ in. (3 in.); aggregates in group 2, 3 in. ($3\frac{3}{4}$ in.).

Cast-in-situ Reinforced Concrete.—Wall containing reinforcement equal in volume to not less than 0·2 per cent. of the volume of the wall, the bars being spaced at not more than 6 in. apart vertically and horizontally in the middle of the wall; (if the wall exceeds 5 in. in thickness a layer of reinforcement should be provided near each face of the wall with not less than 1 in. cover of concrete): 3 in. (3 in.). Solid floor or roof slab: $3\frac{1}{2}$ in.

Hollow Tile Slab.—The minimum cover to the reinforcement should be $\frac{1}{2}$ in. and the minimum combined thickness of the concrete slab and the solid material in the tile should be $2\frac{1}{2}$ in.

Heat Insulation.—Ordinary concrete has slightly less resistance to the passage of heat than has brick. The conductivity should therefore be reduced to prevent a concrete house being cold and to avoid excessive condensation of water vapour on the walls. The precautions include the provision of a cavity wall with an inner leaf of absorbent concrete; the use of an absorbent lining of wood-wool slabs, wallboards, or similar material; or the use of a lightweight concrete for the full thickness of the wall with a waterproof rendering on the outside. With some materials, such as concrete and natural stones, it is generally found that conductivity is reduced as the density decreases; thus lightweight concretes have lower conductivities and therefore smaller heat losses from the structure, and conversely they produce cooler interiors in hot weather. The risk of condensation on a concrete wall or flat roof slab is increased due to the common practice of finishing the inner face with a skim coat only of plaster; it can be avoided by using the ordinary thickness of lime-and-hair plaster, or by lining the walls with an absorbent wallboard.

The conductivity of a material is measured by the amount of heat that passes through a specified thickness of the material in a specified time, and is expressed by the number (k) of British Thermal Units passing through a thickness of one inch of the material in one hour per square foot of surface per degree Fahrenheit difference in temperature between the two faces. The conductivities (k) and densities of several materials used in buildings are given in *Table* I. For some of these materials slightly different values of k are given by different authorities and the figures given in *Table* I (except where marked with an asterisk) are taken from the "Guide" issued in 1942 by the Institution of Heating and Ventilating Engineers.

The greater the value of k the greater is the loss of heat. Thus the resistance to the passage of heat is proportional to $\frac{1}{k}$. Also the greater the thickness d of the material the greater is the resistance. The total resistance to heat passing through a wall or other structural member is the sum of the products of $\frac{1}{k}$ and thickness of each material in the wall or other member. To this sum is added an allowance for any cavity in the wall and the resistances of the outside and inside surfaces of the wall.

TABLE I.—WEIGHTS AND CONDUCTIVITIES OF BUILDING MATERIALS

Material	Weight Lb. per cubic foot	Conductivity k
Asbestos-cement sheeting	96	1·90
Asphalt	140	8·70
Bricks: Common (dry)	110	5·60
,, (northern exposure)	110	8·00
Engineering	137	5·50
Sand-lime	115	7·50
Concrete: 1 : 1 : 2 ballast	140 average	6·70
1 : 2 : 4 ,,	do.	7·00
Clinker (heavy)	105	2·80
,, (light)	95	2·30
1 : 2½ : 7½ foamed slag (dry)	65	1·50
*1 : 6 foamed slag	85	2·20
1 : 2½ : 7½ pumice (dry)	45	1·10
*1 : 6 pumice	50	1·40
Glass	157	7·30
Granolithic	130	6·00
Linoleum	33	1·62
Paper	68	0·96
Plaster: Cement and sand	98	3·70
Cement, lime, and sand	90	3·30
Gypsum	80	3·20
Gypsum and sand	88	4·50
Roofing felt	50	4·00
Sawdust	12	0·41
Slagwool	15	0·30
Slate	161	10·40
Stone: Granite	165	20·30
Limestone	136	10·60
Sandstone	125	9·00
Cast	110	9·20
Terrazzo	152	11·00
Tiles: Clay	120	5·80
Concrete	140	6·50
Wood: Deal	38	0·87
Oak	48	1·11
Pitch pine	41	0·96
Ply	33	0·96
Wallboard: Fibre board (light)	20	0·38
,, ,, (heavy)	27	0·44
Paper pulp board	38	0·53
Plaster board	60	1·10
Wood-wool slabs	25	0·45

The effect of changes of temperature on the outside surface depends on the aspect of the wall and the exposure of the house. The term "sheltered" applies

to a house of two stories in towns; "ordinary" exposure applies to a house in suburbs and rural districts; "severe" exposure applies to a house on a hill, or on the coast or a riverside. For ordinary exposure, the external resistance expressed as degrees Fahrenheit for the transmission of one B.Th.U. per square foot per hour is 0·57 for a wall facing south; 0·43 for a wall facing west, south-west, or south-east; 0·30 for a wall with any other aspect; and 0·25 for a roof. For sheltered houses the external resistances are about 50 per cent. higher than the foregoing, and are considerably lower for severe exposures.

The internal resistance for a wall is 0·7; for a floor or ceiling, 0·60 if the heat flow is upwards, and 0·85 if downwards; and 0·6 for flat or sloping roofs.

The resistance to the passage of heat across an air space, such as a cavity in a wall, is not yet well established, but the recommended value is unity.

The overall heat transmittance (U) of a wall, floor, or roof expressed in B.Th.U. per square foot per hour per degree Fahrenheit difference between the indoor and outdoor temperatures of the air is given by 1 divided by the total resistance. It is advantageous for U to be as low as possible. The desirable value for U for the walls of houses is generally given as 0·15 to 0·20, but, for example, an 11-in. brick wall with an unventilated cavity having a value of as high as 0·30 is generally accepted. Although the desirable value for a ground floor is 0·15, a value of 0·3 is also acceptable. An ordinary wooden suspended ground floor has a value of about 0·25, but a wood-block floor on concrete laid directly on the ground may have a value of about 0·15. The maximum desirable value for a roof is about 0·30, but an ordinary roof of tiles on battens, with felt, and with a plaster ceiling, has a value of about 0·43. Windows and doors are obvious sources of heat losses.

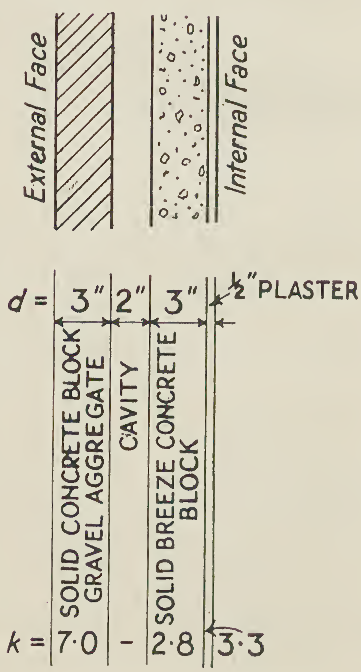


FIG. 1.—HEAT INSULATION.

The following example shows how the heat transmittance for the concrete wall in *Fig.* 1 is calculated, assuming ordinary south-westerly exposure. The values of k are taken from *Table* I.

		Value of U
Resistance of external face		$= 0{\cdot}43$
,, ,, outer leaf	$\frac{d}{k} = \frac{3}{7}$	$= 0{\cdot}43$
,, ,, cavity		$= 1{\cdot}00$
,, ,, inner leaf	$\frac{d}{k} = \frac{3}{2{\cdot}8}$	$= 1{\cdot}04$
,, ,, plaster	$\frac{d}{k} = \frac{0{\cdot}5}{3{\cdot}3}$	$= 0{\cdot}15$
,, ,, internal face		$= 0{\cdot}70$
Total resistance		$= 3{\cdot}75$

Therefore the heat transmittance coefficient is $U = \frac{1}{3{\cdot}75} = 0{\cdot}27$ B.Th.U. per square foot per hour per degree Fahrenheit difference in the temperature of the air inside and outside the house. The total loss of heat from a house is calculated by determining the value of U for each part of the external construction, that is, walls, ground floors, roof, windows, doors, structural frames, lintels, etc., and multiplying this value by the area of each part. The sum of these multiplications times the differences between the inside and outside temperatures gives the total heat loss from which the amount of heat required to maintain the interior of the house at a specified temperature can be ascertained for different external air temperatures.

Sound Insulation.—It is important that party walls be reasonably insulated against the transmission of air-borne noise. The reduction of air-borne sound by a party wall is generally recommended to be 55 to 60 decibels. (A decibel is the unit of measurement of the intensity of sound ; intensity of a sound in decibels is ten times the common logarithm of the ratio of the energy of the sound to the energy of the weakest audible sound of the same frequency. Thus an increase of 10 decibels represents a tenfold increase in the energy of the sound.)

The sound-insulating value of a solid wall of clay bricks or concrete slabs or bricks, or cast-in-situ concrete, increases as the weight per square foot of wall increases ; the insulation value increases approximately in proportion to the logarithm of weight per square foot of solid wall. Lightweight porous concretes are only good insulators if entry to the pores is sealed by a coat of plaster, and even then the sound insulation value of a solid wall decreases as the weight decreases. Walls with cavities are better insulators than solid walls of equal thickness of material, but this enhanced value may be largely nullified by the provision of rigid wall-ties and by securing the edges of the panels of the wall to the surrounding construction.

A reduction of 55 decibels is attained by an 11-in. common brick cavity wall or by a wall of solid concrete blocks of equal weight, or by a cast-in-situ 9-in. wall of lightweight concrete, weighing not less than 80 lb. per cubic foot and

with lath-and-plaster attached to battens on both faces of the wall, or by 6 inches of cast-in-situ ordinary concrete.

Between a living room and other principal rooms, a desirable reduction is 50 decibels, and between other principal rooms 40 decibels. A partition constructed with 2½-in. clinker-concrete blocks plastered on both faces gives a reduction of about 40 decibels.

For the first floor in a house, the desirable reduction in air-borne noise is 60 decibels, but ordinary wooden floors with a plastered ceiling give a reduction well below this amount. Even with acoustically-good concrete the cost of the construction to attain this reduction is generally prohibitive. Against the transmission of noises due to impact on the floor, an improvement in resistance equal to 20 phons over a bare floor is desirable but difficult to attain without undue expense. (A phon is the unit of loudness ; the loudness of a sound, in phons, is the intensity in decibels of a sound having a frequency of 1000 which seems to the ear to be as loud as that of the given sound.) Common methods of floor construction are well below these standards. A reduction of 55 decibels and an improvement of only 5 phons is attained by wooden boards nailed to battens laid on a blanket of resilient acoustical material on reinforced concrete beams (or wooden or steel joists) to which a lath-and-plaster ceiling is attached. Considerable improvement in the acoustical properties of a cast-in-situ concrete floor is attained by suspending the ceiling therefrom, that is, by providing an air space between the underside of the concrete and the ceiling ; bolts or other suspenders should not be rigidly attached to the concrete, otherwise a ready means of transmitting the sound is provided.

CHAPTER II

PRECAST CONCRETE CONSTRUCTION

THE three principal methods of constructing the external walls of houses in precast concrete are by using blocks, posts and panels, and large slabs. The present chapter mainly deals in detail with the planning and construction of houses with concrete blocks, as the other methods are mainly proprietary systems, and also because the laying of concrete blocks presents no difficulty to the bricklayer and no special joints or jointing material are required.

Concrete Blocks.

Concrete in the form of blocks and slabs moulded and hardened before use has been more extensively adopted than any other type of concrete construction, and there are several reasons for this. Some of the advantages are: (1) The blocks or slabs can be made on the site and the cost of carriage reduced to a minimum, or they can be purchased ready for use; (2) They are cheaper than brick or stone; (3) They can be made by unskilled labour, under proper supervision; (4) The cost of laying is less than brickwork on account of their larger size; (5) A considerable saving in mortar is effected compared with brickwork, as there are fewer joints; (6) If hollow blocks or cavity walls are used, the air spaces in the walls result in a more equable temperature inside the building, and pipes and wires can be concealed in the air spaces in the walls; (7) Internal plastering is reduced, as a good surface can generally be obtained with one coat of material only instead of two, as is necessary on brick.

The common form of external wall constructed with concrete blocks comprises an outer leaf of weatherproof concrete and an inner leaf of blocks of concrete with higher thermal insulating properties. The common size of a solid concrete block is $17\frac{5}{8}$ in. long by $8\frac{5}{8}$ in. high by 3 in. thick. Alternatively an external wall can be built with a single thickness of hollow concrete blocks, which are generally $17\frac{5}{8}$ in. long by $8\frac{5}{8}$ in. high by $8\frac{3}{4}$ in. thick, the thickness of the sides being generally 3 in. or 2 in. If the sides are 2 in. thick, the blocks are often stiffened by a central web.

Allowing for the mortar joints, eight solid blocks of the dimensions stated give one square yard of one leaf of a cavity wall, and eight hollow blocks give one square yard the full thickness of a wall. Half-blocks are used for the purpose of breaking vertical joints. Blocks of these types are shown in *Fig.* 2, together with a block of another shape with which a partly hollow wall can be built without metal ties. It should be noted that hollow and tee-shape blocks do not give a continuous cavity. To comply with local by-laws it may be necessary to use blocks that give a greater total thickness of material than those

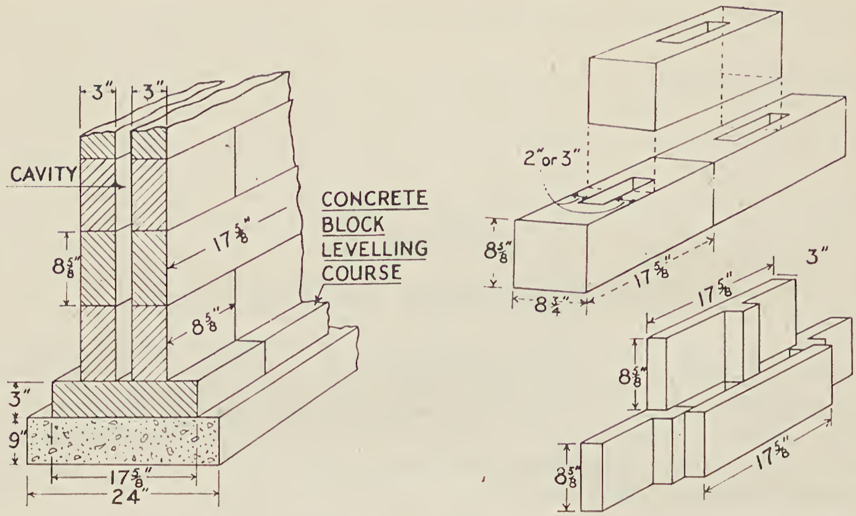


FIG. 2.—SOME TYPES OF CONCRETE BLOCKS.

illustrated, but the principles of construction described in the following apply equally well.

Sections through typical external walls constructed with hollow concrete blocks and with two leaves of solid concrete blocks are given in *Figs.* 4 and 5 respectively.

Foundations.

The blocks are laid directly on a concrete foundation which should project beyond the faces of the wall. The dimensions of the foundation depend upon the nature of the soil and, for ordinary types of houses of not more than two stories, the following rules can be applied. Where the ground is fairly firm the width of the foundation should not be less than twice the thickness of the wall in the lowest story, and the foundation should be provided symmetrically under the wall. The thickness of the foundation should be not less than 9 in. or less than one and one-third times the projection of the foundation from the face of the wall. Thus for a wall constructed of hollow blocks, nominally 9 in. thick, the minimum size for a foundation on firm clay, sand, gravel, or equally firm ground is 1 ft. 6 in. wide by 9 in. deep. It is not always advisable to make the width of the foundation the absolute minimum, owing to the several unknown factors involved in the design, and for this reason 1 ft. 9 in. is the width recommended in *Fig.* 4 for a 9-in. hollow-block wall. For a wall constructed with two leaves of solid concrete blocks, each 3 in. thick with a footing course as shown in *Fig.* 2, the projection of the foundation beyond the footing course need not exceed 3 in. so long as the width of the foundation is not less than twice the total thickness of the wall. Thus if a solid concrete block nominally 18 in. wide forms the footing course, the width of the foundation need not exceed 2 ft., as shown in *Figs.* 2 and 5.

The design of the foundations must comply with the local by-laws, but the foregoing rules are within the requirements of most local authorities.

If the soil is less firm than that described in the foregoing, the width (and therefore possibly the thickness) of the foundation must be increased so that the pressure on the ground is within the limit prescribed for the particular type of soil by the local or other authority. If the soil is very weak it may be necessary to lay over the site of the house a concrete raft, reinforced with a light mesh of steel, and build the walls directly on the raft which will spread the load. Very serious results may occur if the ground is so soft that a raft is necessary and the raft is not properly designed; in such cases it is better not to use the site at all, or, if the site must be used, to obtain a design from an experienced engineer.

If the soil is of a clayey nature or likely to be much affected by atmospheric influence the foundations should be taken below the level of such influence (say, 3 ft.) in order to prevent the wall being endangered by movements which occur with changes of temperature and moisture content. This precaution has not always been taken in cheap work in the past, and in consequence cracks have occurred owing to settlement and other movements. Where the soil contains little or no clay, the foundations need be taken only, say, 18 in. below the surface.

Setting Out.

An important item in the construction of concrete block walls is that of working to suit the length of block employed, both as regards the total length of the wall and the position and the size of the openings. Bond is obtained by placing the blocks at the corners at right angles to one another, so that the quoin is 18 in. wide in one course and 9 in. in the next, and so on; this will also give greatest strength, and no special sizes are necessary.

In working along the length of the wall the openings should be arranged to coincide with the ends of the blocks in one set of courses, half-blocks (*Fig.* 3) being used in the other courses, and the width of the openings should be a multiple of the length of the block employed. The height of the openings should also suit the depth of the courses, as the appearance will not be satisfactory if blocks of odd depths are used or the courses are not continuous, and in addition unnecessary expense and labour will be caused in making or cutting blocks of odd sizes and in laying them. These details should always be worked out on the drawings before the work is commenced. After the drawings have been prepared for one or two houses it will be found comparatively easy and quick to draw subsequent work on the same basis. An example of the spacing of the blocks is given in *Fig.* 3, which shows alternate courses at a corner. These drawings show the use of hollow blocks, but the same principle is adopted for solid blocks whether they are built in one or two leaves.

In the plan of course A there are three complete blocks between the window and the corner of the building, and the centre-line of the window coincides with the centre of the room, which is 12 ft. wide. This necessitates half-blocks in course B to obtain bond, but no odd lengths are required and the work is quite straightforward. The width of the window opening is shown as 4 ft. 6 in., which is equal to the length of three blocks, but it could be increased provided that a multiple of the length of a block be maintained. The next width that could be employed would be 6 ft., and the half-block next to the window would occur in course A instead of course B. If the opening be made equal in width to five blocks, or 7 ft. 6 in., the half-blocks will remain as shown and there will be one

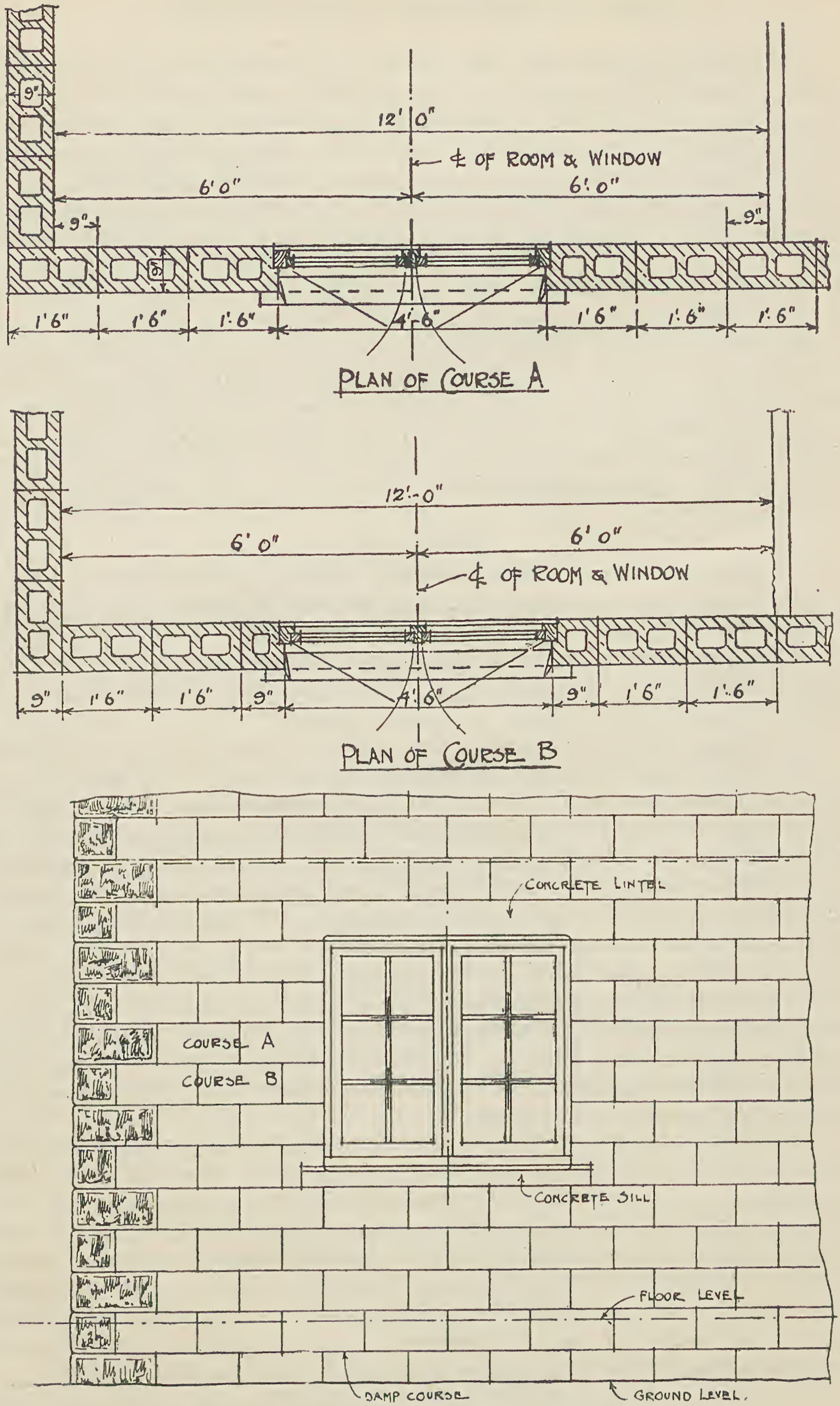


Fig. 3.—Method of Setting-out Blocks.

whole block less in each course between the window and the corner. This example illustrates the importance of working to a multiple of the length of a block, as with a window opening, say, 5 ft. 6 in. wide, considerable labour would be involved in making a satisfactory finish.

A section of a hollow-block wall is given in *Fig.* 4 and it will be seen that the courses are worked up from the foundation and that the openings are

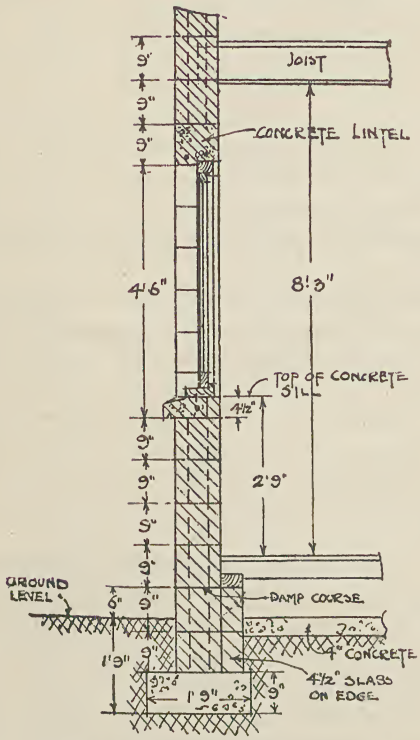


FIG. 4.—HOLLOW-BLOCK WALL.

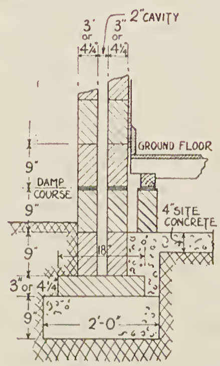


FIG. 5.—CAVITY WALL.

arranged to suit. Concrete lintels and sills should be used with the concrete blocks as shown ; these products are described in Chapter V. The arrangements shown in *Figs.* 3 and 4 are only for the purpose of explaining the general planning of the blocks, and need not be adhered to provided the principle of working to suit the size of the blocks is followed and the openings and walls arranged accordingly.

Erection.

The wall is built directly on the plain concrete foundation as shown in *Figs.* 4 and 5, and a method is shown of supporting the wall-plate under the ground floor joists where a wooden floor is employed. When hollow blocks are used the dampcourse is inserted 6 in. above ground level, and extended through the wall and under the plate.

In building the wall the blocks should be carried up as uniformly as possible in the different parts of the work. The joints should be about $\frac{3}{16}$ in. thick, and

the mortar well flushed up both on bed and at the ends of the blocks, but care should be taken to keep the cavities clear of mortar so as to allow as much freedom for air circulation as possible. If mortar is dropped into the cavity it may connect the outer and inner faces of the two leaves of a cavity wall and conduct moisture through the wall.

For the outer leaf of external walls, cast stone blocks are sometimes used. The body of such a block may consist of ordinary Portland cement concrete with a facing not less than $\frac{3}{4}$-in. thick cast integrally with the block. The facing is generally of special material to give the required colour and texture, as is described in Chapter VIII.

All the external walls should be carried up to the underside of the roof, and arranged so that all the courses are complete. Splayed solid blocks, having the top edge at the same angle as the pitch of the roof should be used for the top course under the eaves and also where gables occur as they avoid cutting and ensure the work being executed without a number of small pieces which are a source of weakness.

Flues and chimney stacks should be built with concrete blocks moulded for the purpose to take any number of flues according to the requirements, and blocks of different sizes are used to give the necessary bond. An alternative method is to build the chimney breasts and flues up to the level of the roof with concrete bricks, which are the same size as clay bricks. If concrete bricks are used the work is executed in the same manner as brickwork, but concrete blocks must be used for the exposed work of the chimney stack above the roof level if a uniform appearance is to be obtained. The construction of chimneys is dealt with in Chapter IV.

Where walls built of blocks are to be rendered externally the appearance of the bonding is not so important, and the work need not be so thoroughly thought out ; but at the same time it is preferable to arrange the spacing and build the walls as if there were to be no outside coating, because in this way the work will be of greater strength and weather resistance.

When solid slabs are used for external walls they are built with a cavity, generally 2 in. wide. In building on the concrete foundation it is best to commence by laying one course of slabs on the flat (*Fig.* 2) forming a course 3 in. high and $17\frac{5}{8}$ in. wide, which is bedded on the concrete foundation and forms a level seating for the blocks which are stood on edge. Two leaves of concrete slabs with a cavity between are satisfactory for house construction, the continuous air space ensuring a dry interior and interior condensation is avoided.

A section through a typical foundation of a cavity wall is given in *Fig.* 5 where the method of laying the first course is seen. The dampcourse should be inserted above the ground level (*Fig.* 5), and it should extend through the two thicknesses in separate layers ; otherwise any moisture which finds its way into the cavity will run down on to the dampcourse and the cavity will become a form of gutter, the moisture will in time pass into the inner thickness of concrete, and the object of the cavity will be defeated. By executing the work as recommended any water in the cavity will drop to a point below the dampcourse, and if the moisture passes through the inner wall below the level of the latter no damage will be done as it will be unable to rise into the work above the floor. The inner and outer leaves of the wall are tied together with

wall ties, one at least being provided for every square yard of wall. The ties should be galvanized or tarred and sanded, and they should have a dip or twist in the centre of their length to prevent water running across them from the outer to the inner leaf. In placing them in the work they should be staggered, that is a tie should be placed in the centre of the space between the ties immediately above and below, and care should be taken that mortar is not allowed to drop on to the ties and remain there, as this will prevent the twist or dip being effective in throwing off water.

Window and door frames in cavity walls where the head is exposed to the possibility of water dropping down the cavity should be covered by a layer of impervious material, built into the two thicknesses across the cavity to form a gutter with the ends carried beyond the width of the frame to throw water clear. In good-class work 4-lb. lead is often used, but in cheap work zinc or bituminous sheeting is used. It must be understood that the outer leaf, which is only 4 in. thick, may not be entirely weatherproof, and the object of the cavity is to form a break between the outer and inner leaves which will prevent the passage of moisture ; any unprotected woodwork in the cavity will therefore be liable to become damp and also to conduct damp to the inside of the house. The cavity should be well ventilated at the top and bottom to ensure free circulation of air, as this will assist in keeping it dry. The remarks on the necessity of spacing the openings to suit the size of the blocks, and similar notes given in connection with the use of hollow blocks, also apply to double walls.

Mortar.

Concrete blocks may be bedded in mortar composed of 5 parts of clean sand, 1 part of lime, and 1 part of Portland cement, or they may be bedded in lime mortar and pointed with sand-cement mortar in the proportions of $2\frac{1}{2}$ or 3 parts of sand to 1 part of Portland cement. For walls built of cast stone blocks a dense rich mortar is not desirable, as the joint may then be stronger than the block with the consequent risk of cracking because the concrete will not be able to contract and expand at the joints. The best jointing material is one which has good workability and moderate strength and density. It is recommended by the British Cast Concrete Federation that these properties be obtained with the use of hydraulic lime mortar or a mortar made of lime gauged with cement. The following limes are suitable : Hydraulic (Lias) lime slaked by experienced masons ; hydrated hydraulic lime ; hydrated greystone lime (in winter this may with advantage be gauged with a proportion of Portland cement) ; and white hydrated lime gauged with Portland cement in the proportions of 4 : 1 by volume. In each case suitable proportions of clean and fairly fine sand or crushed stone free from an excess of dust should be added. Another suitable material is lime putty and sand gauged with Portland cement in the proportions of 10 : 1 by volume. Any of these mixtures is also suitable for pointing, using white or coloured cement if required, and for this purpose it may be necessary to use less aggregate in order to obtain the required workability.

Weather Resistance.

Concrete blocks made by hand or in pressure machines with " semi-dry " concrete are porous. Also, any shape of block with a web of concrete from the

outer to the inner faces of the wall, as the hollow blocks in *Fig.* 2, will conduct moisture to the inner face. Walls built with these types of blocks must therefore be faced on the outside with a waterproof rendering. Provided that the outer leaf is built with waterproof concrete blocks, such as cast stone, no rendering is necessary.

Large Precast Concrete Slabs.

Since 1939 many new ideas have been put forward, particularly with the object of saving labour on the site by the use of large wall sections precast in a factory. Some figures of the labour saved on the site in the case of concrete houses compared with brick houses were given in 1947 by Mr. R. Fitzmaurice, B.Sc., of the Building Research Station. He said that the saving in labour on a concrete house poured in situ on a highly-organized site was 36 per cent. on the shell complete with doors and windows, making the saving in labour for the whole house 13 per cent. On a house with posts and panels in precast concrete the total saving on the shell was 48 per cent. and on the whole of the house 17 per cent. In another type of precast house the comparative figures were 40 per cent. and 14 per cent. In the case of a house built with very large panels requiring a crane to handle them the figures were 36 per cent. and 13 per cent., and in the case of another house with still larger panels the figures were 41 per cent. and 10 per cent.

An example of the use of large precast concrete wall slabs is the method used by the Glasgow Corporation. The slabs are made in a factory built by the Corporation in the year 1945 and which is able to make sufficient slabs for 2000 houses a year. The slabs, the largest of which measure 10 ft. by 8 ft. 8 in.

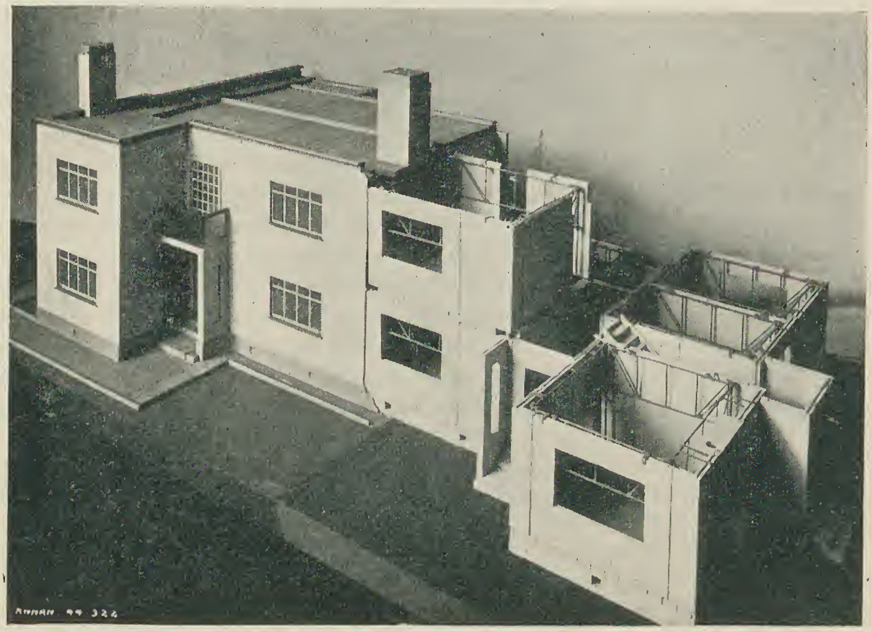


FIG. 6.—MODEL OF PRECAST CONCRETE HOUSES BUILT WITH LARGE SLABS.

by 6 in. thick, are of lightweight concrete mixed in the proportions of 1 part of Portland cement to 3 parts of foamed slag from $\frac{1}{8}$ in. to dust and 4 parts of foamed slag from $\frac{1}{2}$ in. to $\frac{1}{8}$ in. A photograph of a model showing the design of the houses is given in *Fig.* 6, and a photograph of a slab being removed from its mould is shown in *Fig.* 7.

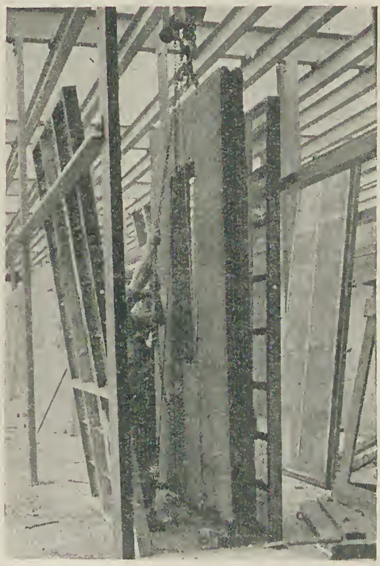


FIG. 7.—REMOVING LARGE WALL SLAB FROM THE MOULD.

Precast concrete slabs with a brick face have also been used for houses. These are made by placing in the bottom of a mould a layer of brick-tiles about $1\frac{1}{2}$ in. thick and spaced apart the width of a mortar joint. Cement mortar is poured over these tiles and into the spaces between them, followed by a backing of concrete to give the required thickness of wall. In the case of 150 houses built for the Ministry of Health in 1947 the slabs measured 6 ft. long by 2 ft. $8\frac{1}{2}$ in. high, and they were 8 in. thick in the lower story and 6 in. thick in the upper story ; the brick tiles were staggered at the ends of the slabs so that a continuous vertical joint was avoided when the slabs were erected, and the walls resemble brickwork.

Precasting Complete Walls.

The idea of precasting complete walls and floors of houses and erecting these large slabs by a crane is an attractive one. The disadvantages are the cost of the plant for handling the slabs and the need to use steel reinforcement which is required to prevent the slabs from cracking when they are lifted but which is not necessary when they are in position. However, the precasting of complete walls for concrete houses has been in use for some years. Some houses at Cambridge were probably the first to be built on this system in England. These were two-story houses with a floor area of 937 sq. ft., and they were built for the Cambridge Corporation in 1927 at a contract price of £475 each.

On each side of each row of houses was laid a narrow-gauge rail track on which travelled a transporter which could pick up slabs from either side of the track and place them in position in the houses between the tracks. Each pair of houses consisted of fourteen slabs; the front and back of each house was made up of two slabs, one for the ground floor and one for the upper story; the end walls of the pair were formed of two slabs, one for the ground floor and one for the upper floor; while the party wall to each floor was precast as one slab.

The slabs were moulded on wooden platforms beside the site of the house of which they were to form part. Window and door frames were placed in position before concreting commenced. Breeze concrete was used for the inner face and ballast concrete for the outer face. The slabs were made with the inner face at the bottom. Two inches of 1 : 7 breeze concrete were first spread over the platform; next was placed $3\frac{1}{2}$ in. of breeze without cement or other binding agent; and finally a 2-in. layer of 1 : $4\frac{1}{2}$ ballast concrete to provide a weatherproof external face. A skimming coat of plaster was used on the inner faces of the walls. The core of loose breeze was used to provide insulation. The surface of the ballast concrete was scrubbed about 24 hours after it had been poured in order to expose the aggregate.

At the corners and at window and door openings the loose breeze core was replaced by ballast concrete, so that at these places there were gravel concrete piers $5\frac{1}{2}$ in. thick. At the top of the slab, over window openings, etc., the loose breeze was also replaced by ballast concrete. Reinforcement was placed in the ballast-concrete piers and beams. As the upper part of the houses was to be tile-hung, and there was thus no need for a weatherproof face to the slabs, breeze was used throughout for the walls to the upper stories.

When the concrete was placed, iron rods with hooks at the end were embedded in the concrete for use when the slabs were lifted by the crane. With ordinary Portland cement the slabs were left ten days to harden, but with rapid-hardening Portland cement it was possible to hoist the slabs two days after casting.

The first slab erected for each pair of houses was held in position by struts until a slab was placed at right-angles, when the interlocking lugs by which the slabs were connected was sufficient to hold them vertical without other support. The lower slabs were bedded in mortar on the footing, and mortar was placed on the top of the slabs to receive the slabs for the upper story. Partition walls were cast in one piece on a platform and hoisted into position in the same way. These were 2 in. thick of breeze concrete for the upper floor and $4\frac{1}{2}$ in. for the ground floor, and a moving platform was used to prevent them being broken during erection. Floors and roofs were built of wood.

More recently the system has been used abroad, and the method of making the slabs in a factory and of erecting them on the site adopted by the Housing Commission of Victoria, Australia, in the year 1947, is described in the following.

On a bench the shapes of the walls are painted, together with the positions of door and window openings, conduits, ventilators, reinforcement, and other details. Steel mesh reinforcement is taken from a roll and laid on the bench and cut out to the pattern. Steel bar reinforcement is then placed in the positions shown on the pattern and wired to the mesh. Electrical conduits, switch-boxes, and wooden plugs to form holes through the walls where necessary are then fixed in position, and the assembly is then taken to the concreting line where it is laid

on a bench with a steel top measuring 30 ft. by 9 ft. 7 in. At this stage there are placed in position the cores, with screwed sockets attached, to fix the walls at corners (*Fig.* 8) ; pieces of angle-iron, with brackets attached, to be cast into

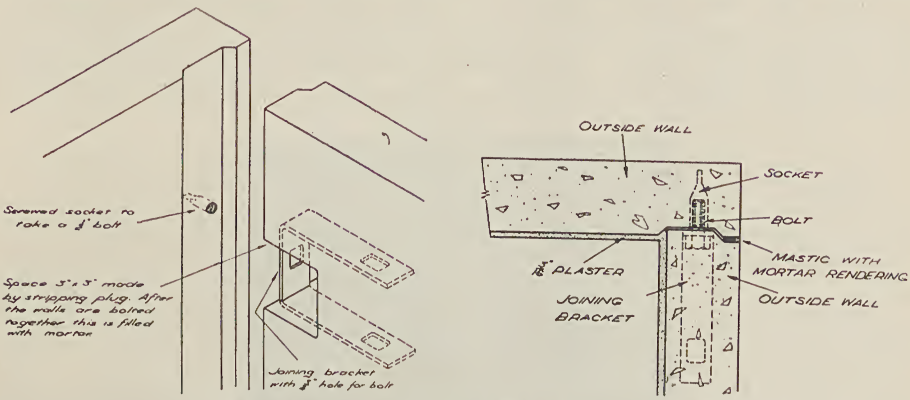


FIG. 8.—METHOD OF JOINING LARGE PRECAST SLABS.

the ends of the wall ; the mould sides held in position by lugs along the edges of the bench ; steel frames, with wooden plugs attached, for forming wall openings and to enable door and window frames to be screwed into the plugs which are

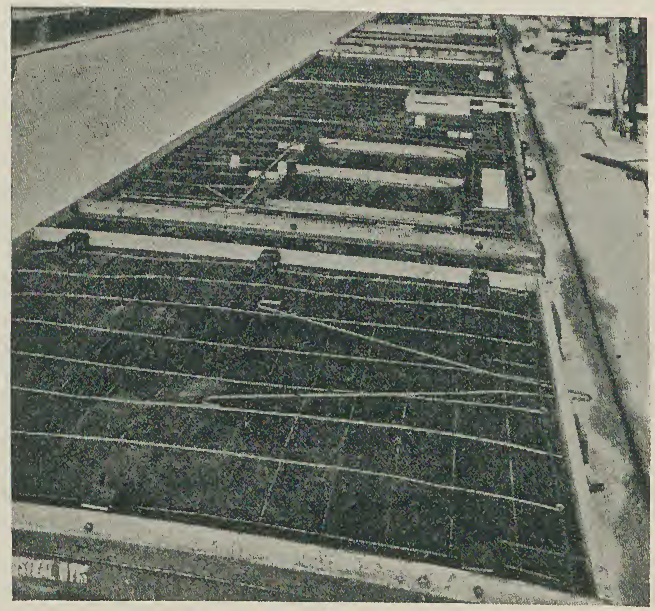


FIG. 9.—MOULDS READY FOR PLACING CONCRETE FOR COMPLETE WALL.

left in the wall ; and ventilators to be cast in the wall. The steel frames for forming openings are kept in position by passing pins through holes in the frames into corresponding holes in the bench-top ; it is proposed later to cast steel

window frames directly in the walls. Moulds ready for concreting are shown in *Fig.* 9.

The concrete is obtained from an adjacent ready-mixed concrete plant, and is taken over the casting benches in a 3-ton skip by an overhead transporter. The concrete is dropped into the moulds through a gate in the bottom of the skip and spread by shovel. Consolidation is effected by an electrical vibrating screed, and the surface is smoothed by wooden floats ; at this stage wooden plugs

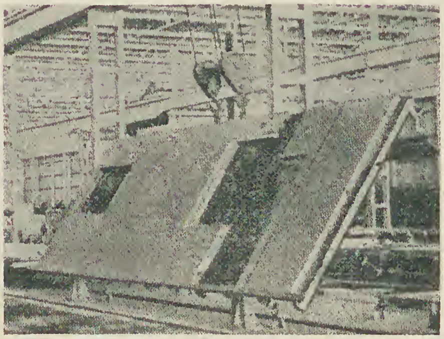


Fig. 10.—Removing a Wall.

for fixing cupboards and other fittings are fixed in the concrete. The day after it is cast the wall and bench-top are removed (*Fig.* 10) to curing racks where the bench-top and the inserts to form the openings are removed for re-use ; the timber forming the bottom edge of the mould is left in position to support the wall while it is hardening. After curing for three weeks the walls are taken to the site in a vertical position on a truck capable of carrying 20 tons. At the site

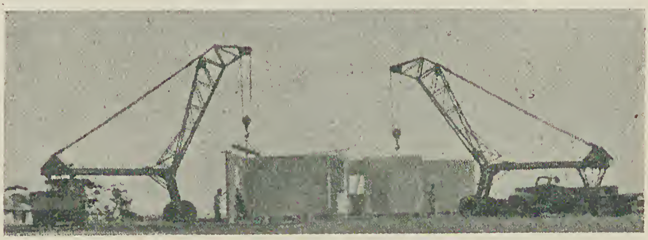


Fig. 11.—Erecting Precast Concrete Walls.

the walls are erected by 10-ton mobile cranes (*Fig.* 11), and they are fixed together by $\frac{1}{2}$-in. bolts passing through a U-shaped bracket in one wall into a threaded socket in the other wall (*Fig.* 8).

In an American method the slabs are cast on the site on benches about 3 ft. above ground level and which can be tilted to a nearly vertical position when the slabs are hard ; in this case the slabs are lifted by a crane on a crawler track which places them in position.

CHAPTER III

DESIGNS FOR HOUSES BUILT WITH PRECAST BLOCKS

THE designs in this chapter have been drawn as a guide to those who have no previous experience of this class of work. In preparing the designs the following principles, which are important if a satisfactory and economical house is to be obtained, have been kept in mind: (*a*) The adoption of a straightforward plan without numerous breaks in the walls; (*b*) a simple treatment of the elevation with a predominance of horizontal lines; (*c*) the provision of a flat roof as being the most suitable for concrete construction; (*d*) the use of concrete wherever the material can be economically applied.

No attempt has been made to add elaborate features, as they would add to the cost and simplicity would not be achieved. Although a similar treatment has been adopted for each of the designs, the designer is not limited in this respect, as it is a simple matter to make considerable variations by using coloured blocks throughout or in the form of bands, or by forming panels, stringcourses, pilasters, and similar features, or by applying roughcast or other material. The provision of pitched roofs for some houses lends additional interest to a group. Illustrations of possible variations are given in the perspective drawings by the late T. Raffles Davison, Hon. A.R.I.B.A., which show how the character of the houses may be readily changed and how additional features can be embodied.

No attempt has been made to deal with drains, fences, paths, or other items which must be governed by the site, but the items omitted will not materially affect the application of the designs to any ordinary site.

TYPE NO. 1 (*Figs.* 12 to 19).—The ground and first-floor plans are illustrated in *Fig.* 17. This is the smallest type of house, without a parlour and with two bedrooms only. The rooms are of fair size and the accommodation will sometimes be sufficient. A bathroom is provided on the first floor. Should it be necessary to change this arrangement there is ample room for a bath in the kitchen, and a small third room would then be available on the first floor. The plan is a simple one with all the drains at the back of the building, and the houses could be erected in pairs or in blocks of four as shown in *Figs.* 25 to 29.

TYPE NO. 2 (*Figs.* 20 to 24).—This is a slightly larger house of the non-parlour type, with three bedrooms and a bathroom on the first floor. The living-room is large, and the front bedroom is of similar size; the other rooms are of useful size with ample provision of cupboards. The total floor area is 946 sq. ft. The provision of a parlour in either Type No. 1 or Type No. 2 would entail considerable addition to the floor area or the reduction of the size of the living-room to an extent which would render it unsuitable for the majority of tenants.

A method of grouping Types Nos. 1 and 2 to form a block of four houses is

illustrated in *Figs.* 25 to 29, and it would be possible to increase the group to six or eight houses if necessary.

Type No. 3 (*Figs.* 30 to 37).—This is a larger house with a parlour and three bedrooms. The staircase is at the back of the house to allow two rooms in the front on a 28-ft. frontage, and the entrance to the kitchen is out of sight from the front door. The w.c. is separate from the bathroom, and the bedrooms are grouped around the staircase to make a compact first-floor plan. The blank wall at the side of the house on the ground floor will permit the addition of a garage in a convenient position.

These three types are simple rectangular buildings without outbuildings or projections, thus making the construction economical. The drains in each case are at the back, and the objection to a bathroom and w.c. at the front is overcome, thus giving greatest convenience at least cost.

Type No. 4 (*Figs.* 38 to 45).—These drawings show a single-story house that is suitable when entrance directly into the living-room is not an objection. A large living-room and three bedrooms are provided, while the bathroom is at the back of the living-room fireplace to obtain quick circulation of hot water. If three bedrooms are not required, the one close to the bathroom could be omitted and the front external wall carried through in a straight line. The plan allows all the drains to be at one corner of the house. If entrance directly into the living-room is not desired, the side window in the porch opposite the w.c. could be converted into a door and access obtained to the corridor. The cross-sections show different methods of roofing, and it will be noticed that the flat roof shows a considerable saving in the total cost.

Type No. 5 (*Figs.* 46 to 54).—This single-story house is smaller than Type No. 4. The accommodation includes a living-room of medium size, two bedrooms, a kitchen, and the usual offices. Two w.c.'s are provided. Hot water for the bath would be supplied from the living-room fire, and the linen cupboard and bathroom are close to this to reduce the lengths of the pipes. The plan provides for the drains to be at the back of the house. A separate entrance with a porch is provided at the side, but if access is arranged directly into the living-room the area of the house could be slightly reduced with a saving in cost.

Elevations.—As before mentioned, a simple treatment has been adopted for the elevations, and instead of ornament, projections, gables, and other features, an attempt has been made to get a successful effect by the use of good proportions. It may be considered that the houses are not sufficiently picturesque, but it does not necessarily follow that they would not look pleasing because they are not traditional in character. Much depends on the environment. The flat roof slab generally has been projected beyond the face of the wall for a distance of 18 in., and in this way a good shadow would be obtained. Simple coloured concrete bands or courses may be used to increase the horizontal effect and give a sense of proportion to the upper and lower stories. Much will depend on the colour and texture of the facing blocks. It is proposed that these should be made with selected aggregate and treated by one of the methods mentioned in Chapter VIII, to avoid the grey monotone effect often associated with concrete buildings.

In all types an alternative perspective is given showing a pitched roof, but this is only put forward to illustrate the possibilities and it is not proposed that pitched roofs be used except where they are required to provide variation in a

large group of houses, or where the environment is unsuitable for flat roofs. Other variations are shown in the drawings.

With regard to the elevations generally, an attempt should be made to envisage the completed buildings, which will possess character that cannot be expressed on a drawing, and also to put aside any prejudice that may be felt against the use of a style and material which are different in appearance from that to which one is generally accustomed.

In houses a long and low elevation will be more pleasing than a short and high one, and in this respect it will be seen that the flat roof is more successful, as the addition of the pitched roof adds considerable height to the buildings, and what is gained in picturesque appearance may be offset by the loss of better proportion. In the drawings for houses of one story a pitched roof as an alternative is also indicated. As the buildings are low the effect of the pitched roof in these cases is pleasing because the additional height does not entail a loss of good proportion. As previously mentioned, however, a pitched roof considerably increases the cost without increasing the accommodation.

WALLS.—A working detail of the front elevation of Type No. 1 is given in *Fig.* 16. The bonding of the blocks in elevation is indicated, and agrees with that shown in the block-bonding plans referred to earlier. This detail is typical of the other types, for which it is not considered necessary to give a large-scale detail. The construction of the walls and floors is indicated, and, if this drawing is taken in conjunction with the other details and the quantities, no difficulty should be experienced in preparing the design and erecting the house.

The slabs generally provided for are nominally 18 in. by 9 in. by $4\frac{1}{2}$ in. thick, and the external walls are arranged to be built of two $4\frac{1}{2}$-in. leaves with a 2-in. cavity, but blocks 3 in. thick can be used equally well if certain of the secondary dimensions are slightly altered. The external blocks should be made of dense hard concrete, and the aggregate may be exposed while the concrete is green to give a good texture and colour; the inner blocks should be made of porous concrete with breeze or other suitable aggregate to ensure a wall free from condensation. The internal partitions are shown as constructed with $4\frac{1}{2}$-in. blocks on the ground floor or where weight has to be carried, and with 2-in. blocks on the upper floor when used as a division only and not as a structural member. The party walls can be constructed in a similar manner to the external walls with a cavity and using porous blocks throughout, or with 18 in. by 9 in. by 9 in. hollow blocks as provided for in these designs. It will be noted that the internal partitions are bonded to each other and to the external and party walls at every alternate course as a minimum.

Details of floors, stairs, doors, roofs, lintels, sills, and other parts of the construction are described in Chapter V and methods of manufacture in Chapter VI.

QUANTITIES.—A bill of the quantities required for each type of design is given in Appendix II in a concise form in order to facilitate reference. All preliminary items have been omitted, as these are only required when a contract is being entered into, and it is a simple matter then to add these items.

Elaborate descriptions and specifications have been avoided, as the methods necessary for good work are dealt with in other chapters and notes have been added where necessary to call attention to any particular detail or item. The quantities as presented are practically "builders' quantities," and in addition

the numbers of blocks and similar items are added where these may be useful. The several types are grouped together in one bill to avoid repetition of the descriptions and to make comparison of quantities between any two types an easy matter. Some items such as drains, site levelling, paths, fences, and similar matters, have been omitted as these could not be accurately determined unless particulars of an actual site were available. These items would be added by the architect or builder to make up the total bill, and their omission does not affect the accuracy of the quantities given.

To arrive at the estimated cost of any type, the contractor can fill in the unit price at which the work in each item can be executed and make the extensions and totals and include allowances for preliminaries and site work. In making this estimate it would be advisable to look through the quantities first and prepare a list of the items which are not included and which are dependent on local conditions, in order to ensure that provision is made for everything. At the end of the bills of quantities are given the floor areas and cubic contents of each type of house.

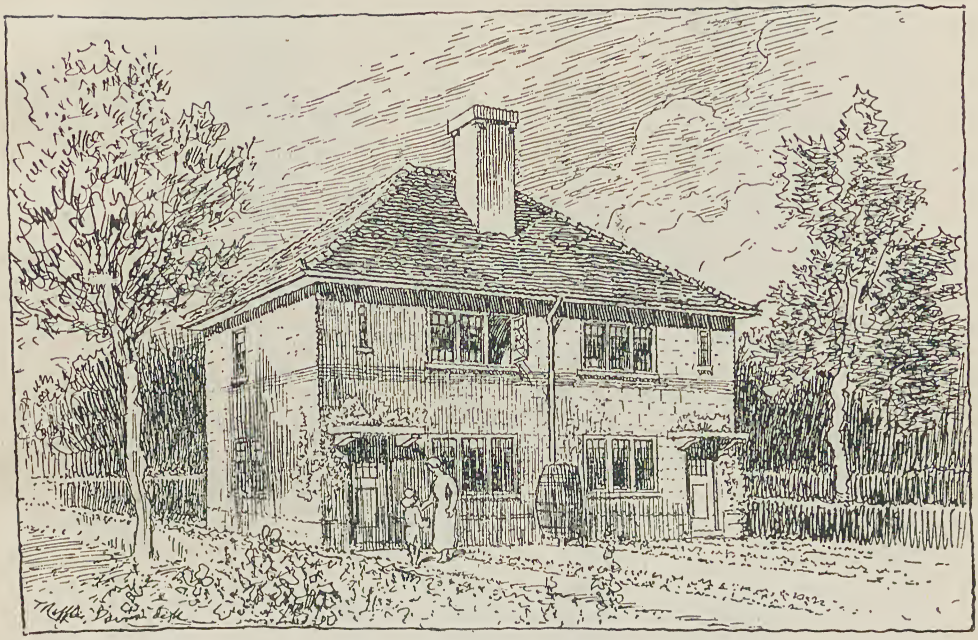


FIG. 12.—SKETCH SHOWING VARIATION OF TYPE NO. 1.
(See *Figs*. 13 and 14).

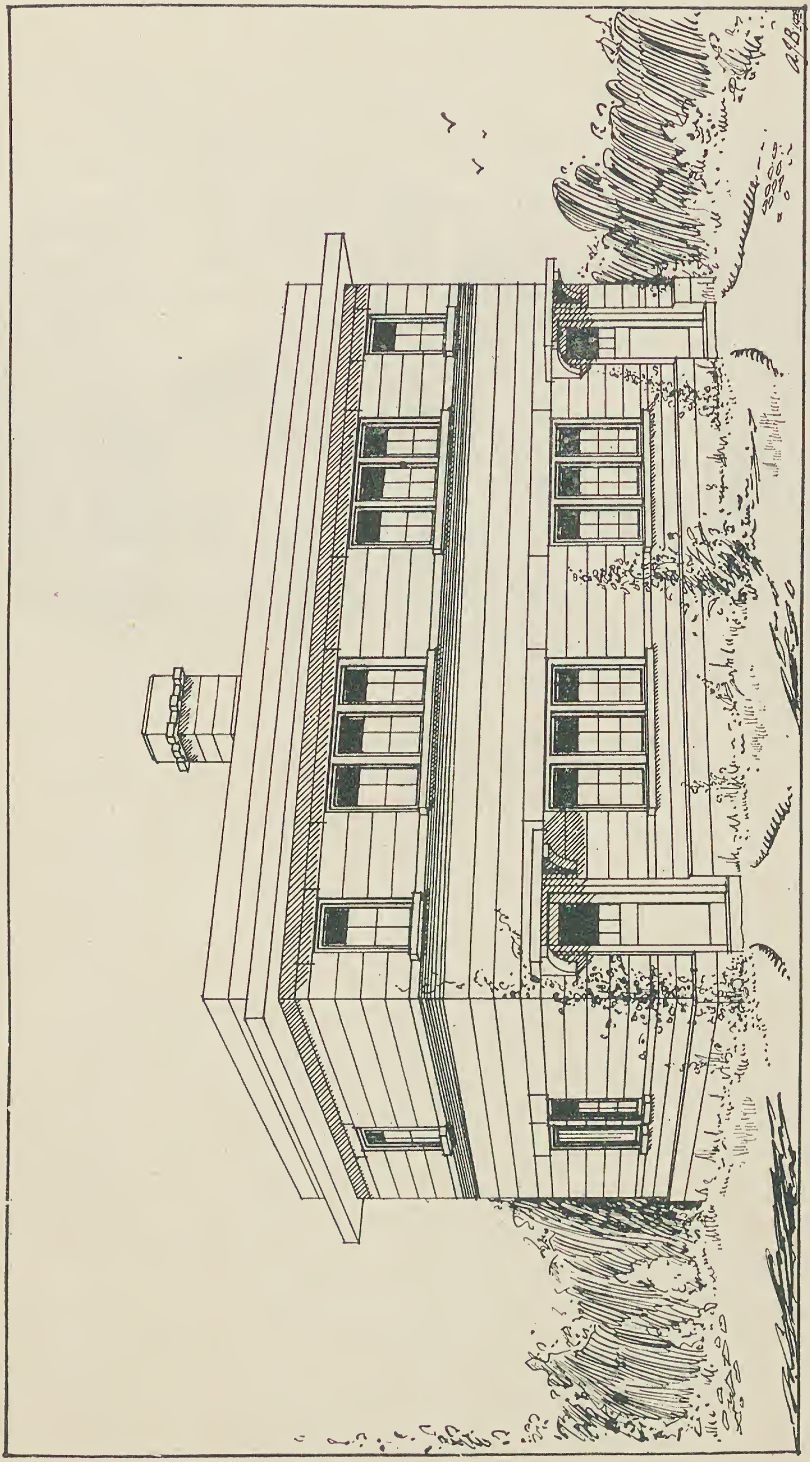


Fig. 13.—Type No. 1: Perspective.

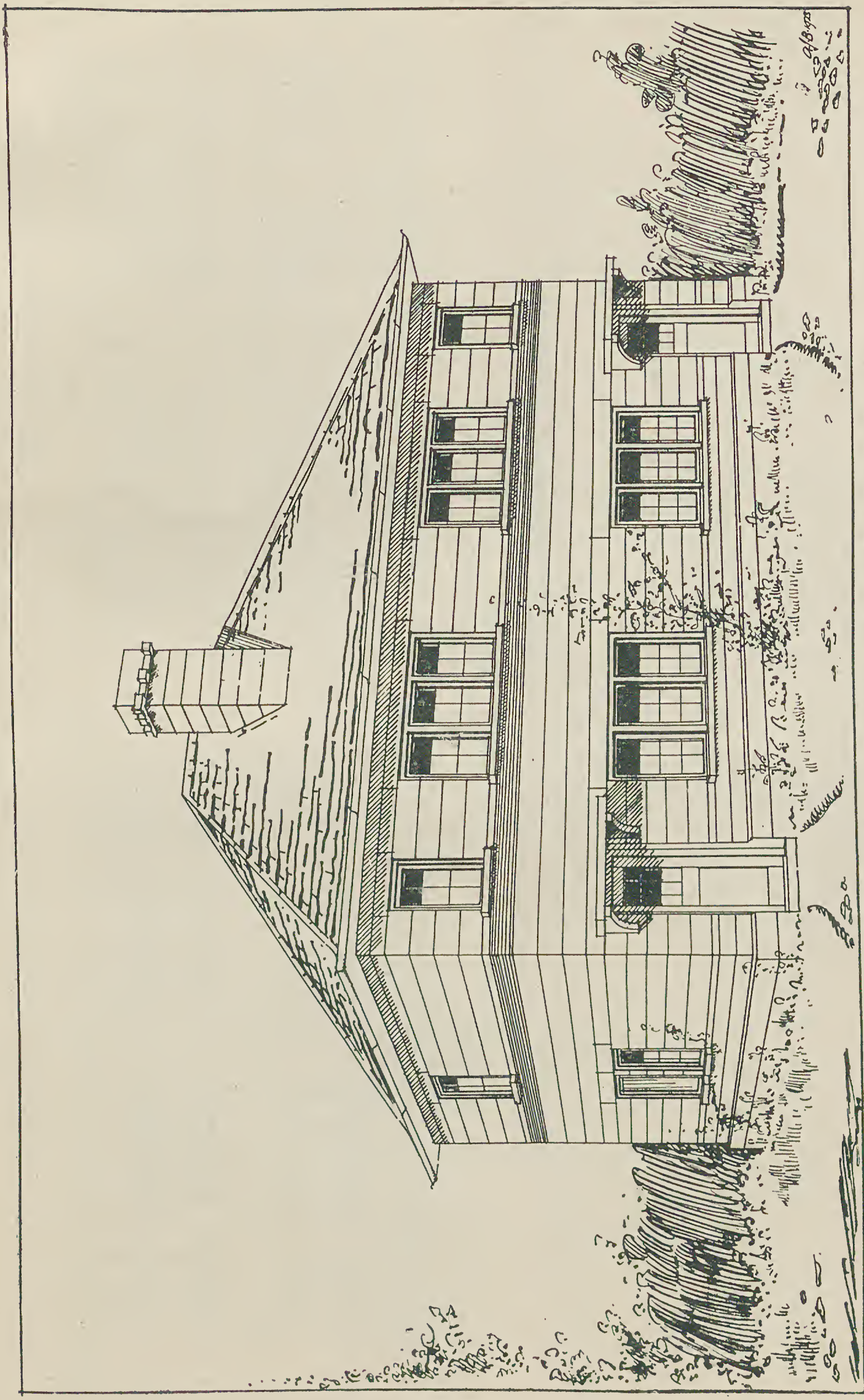


Fig. 14.—Type No. 1: Perspective with Pitched Roof.

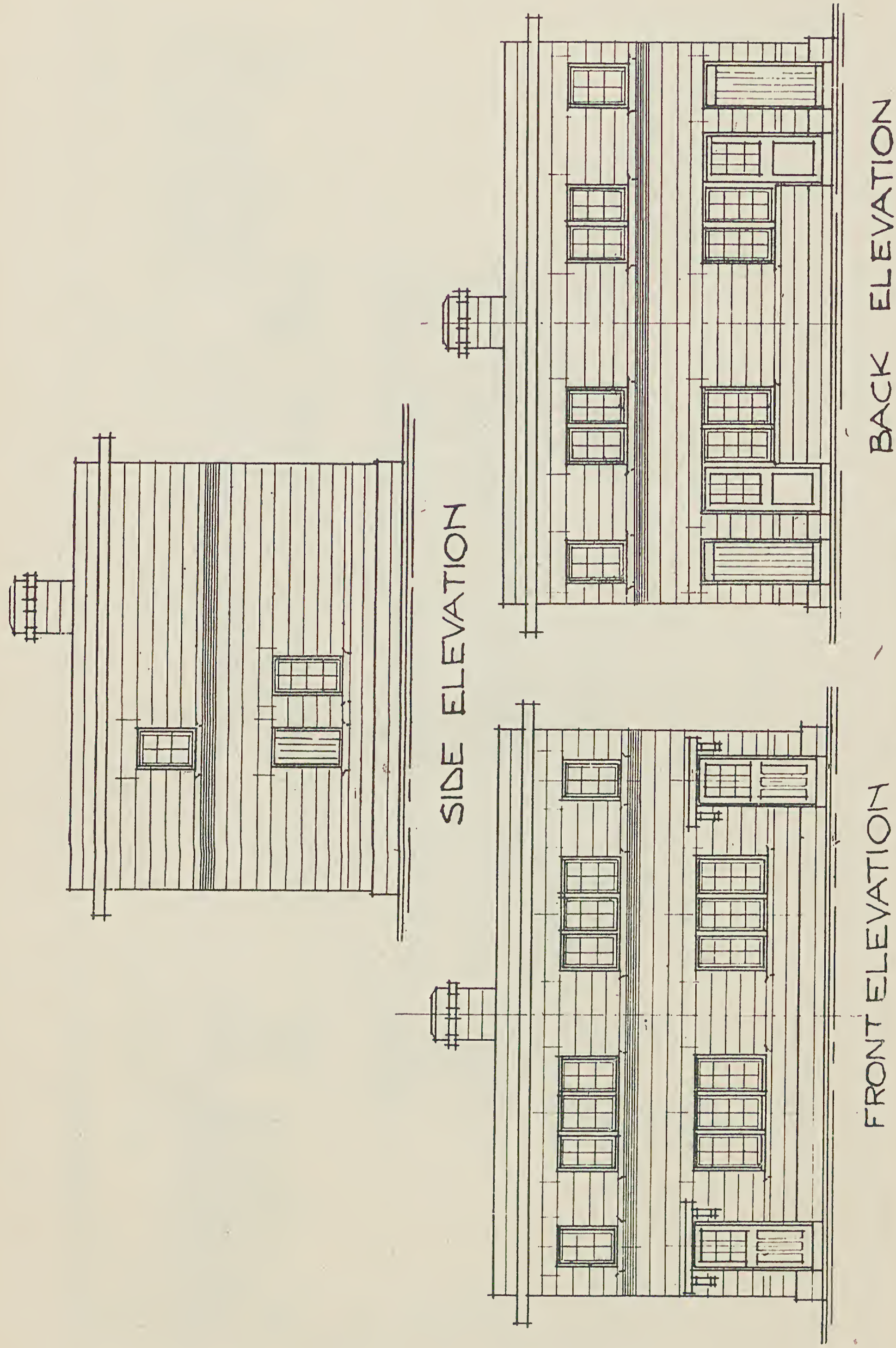


Fig. 15.—Type No. 1: Elevations.

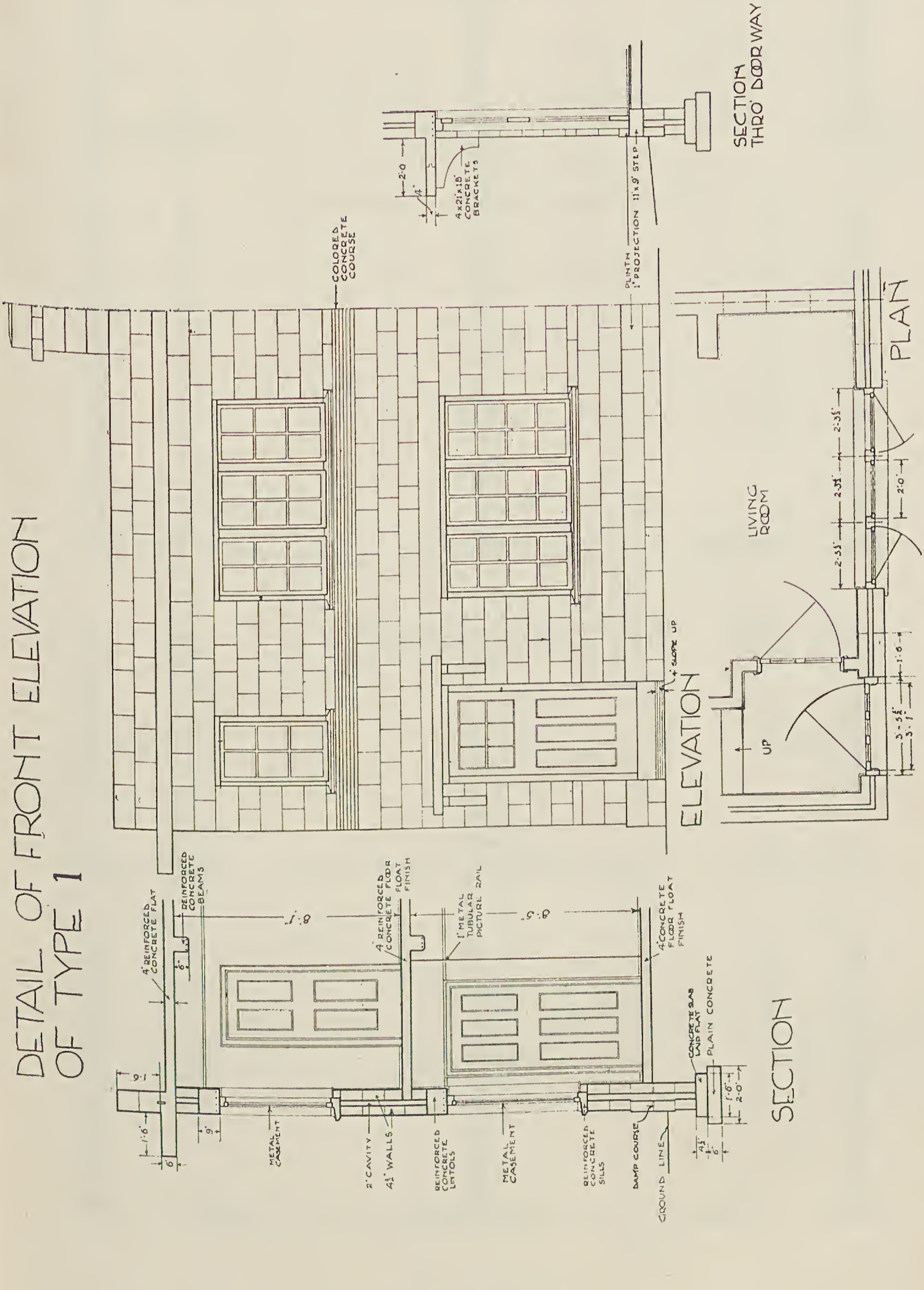
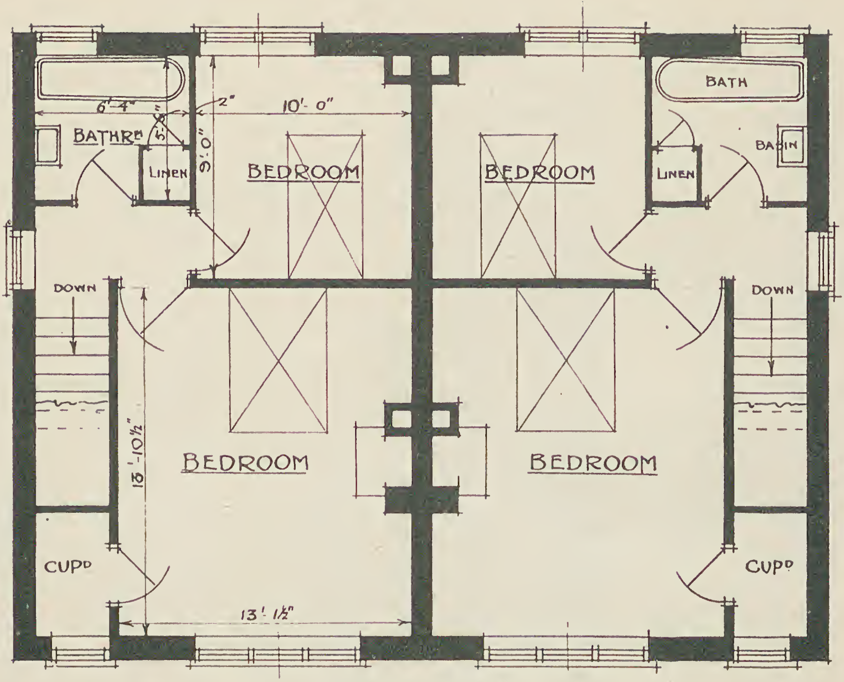
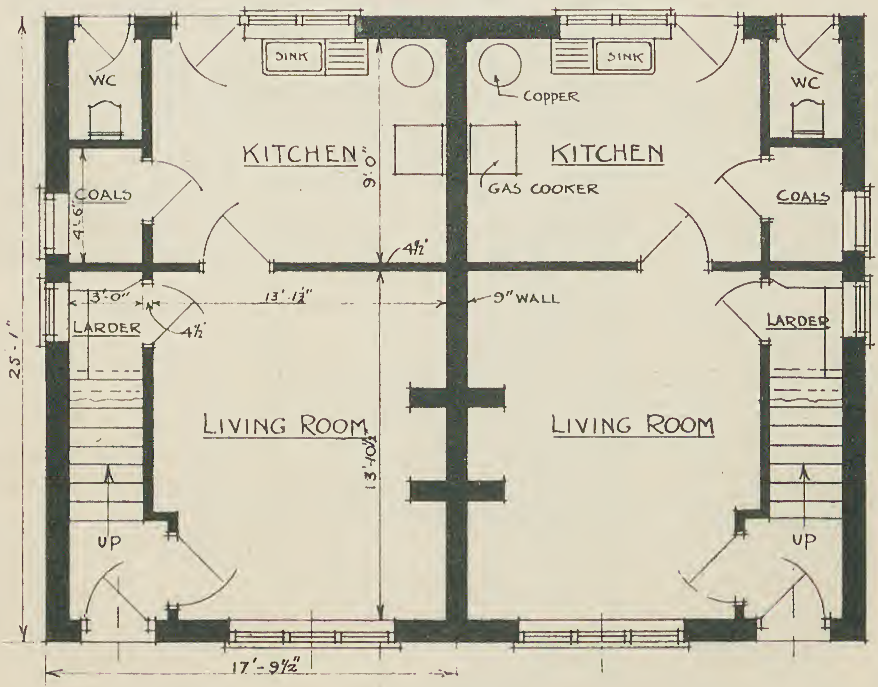


Fig. 16.—Type No. 1: Detail of Front Elevation.



FIRST FLOOR PLAN.



GROUND FLOOR PLAN.

FIG. 17.—TYPE No. 1: PLANS.

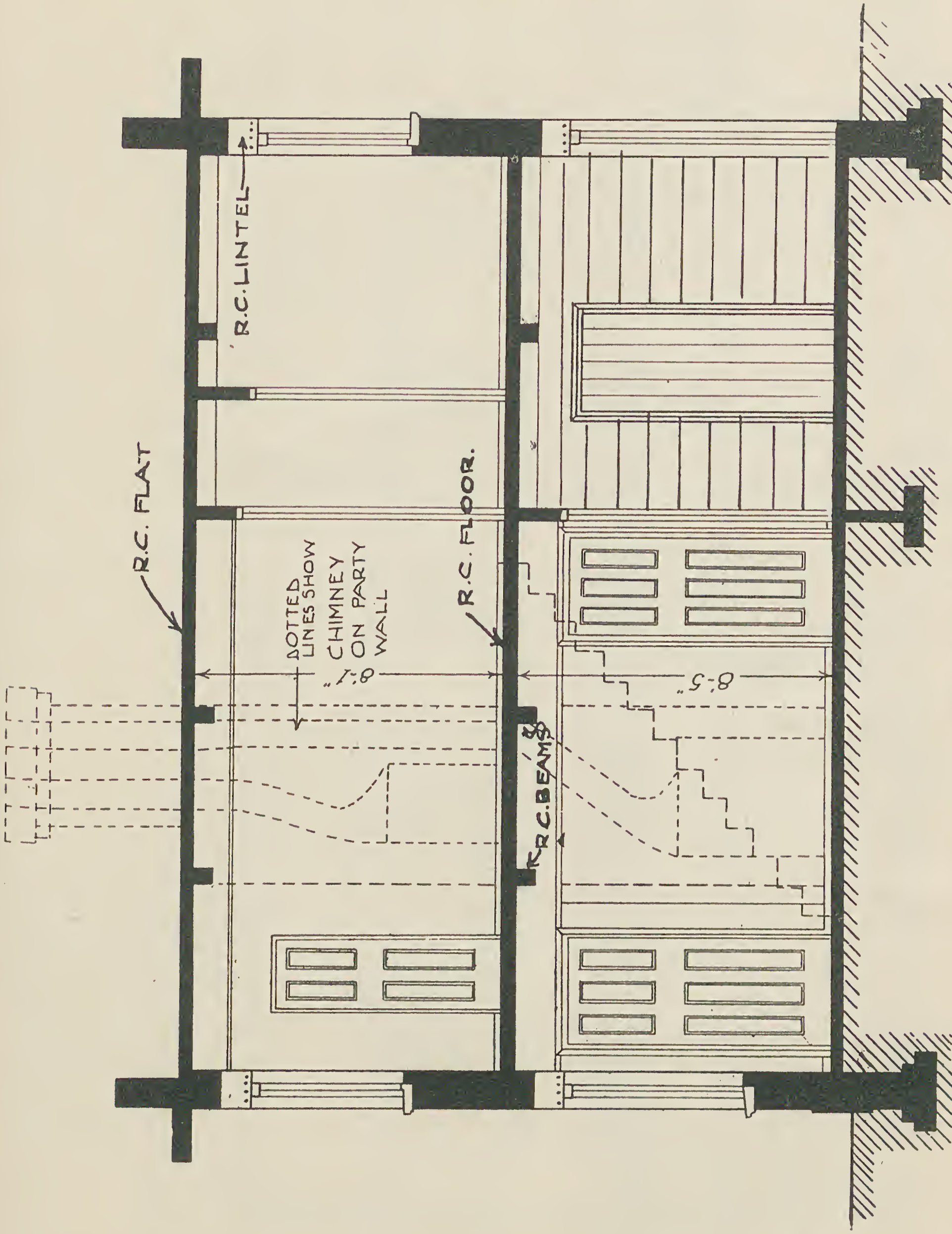


FIG. 18.—TYPE No. 1: CROSS SECTION.

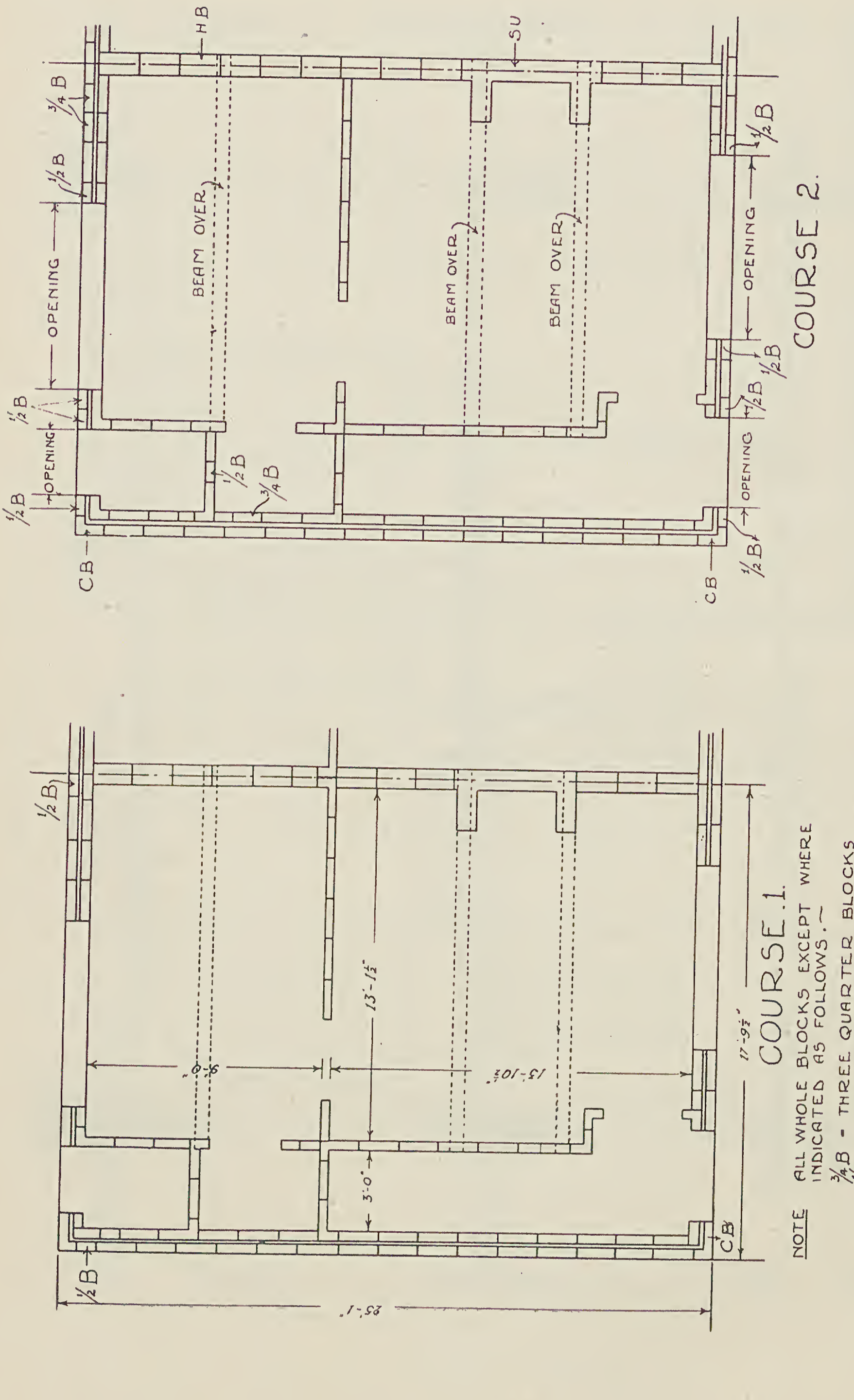


Fig. 19.—Type No. 1: Plans showing Bonding of Blocks.

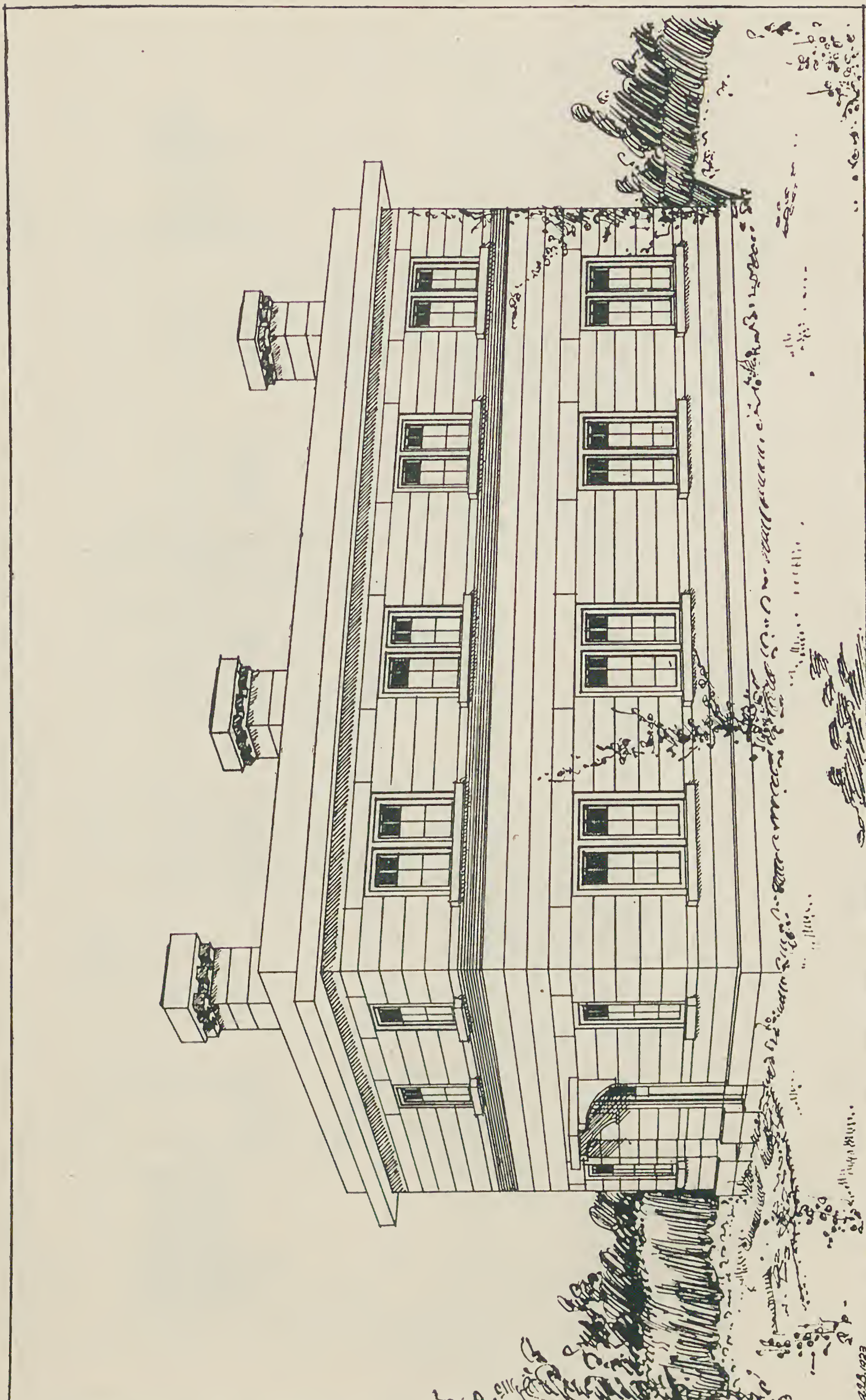


Fig. 20.—Type No. 2: With Flat Roof.

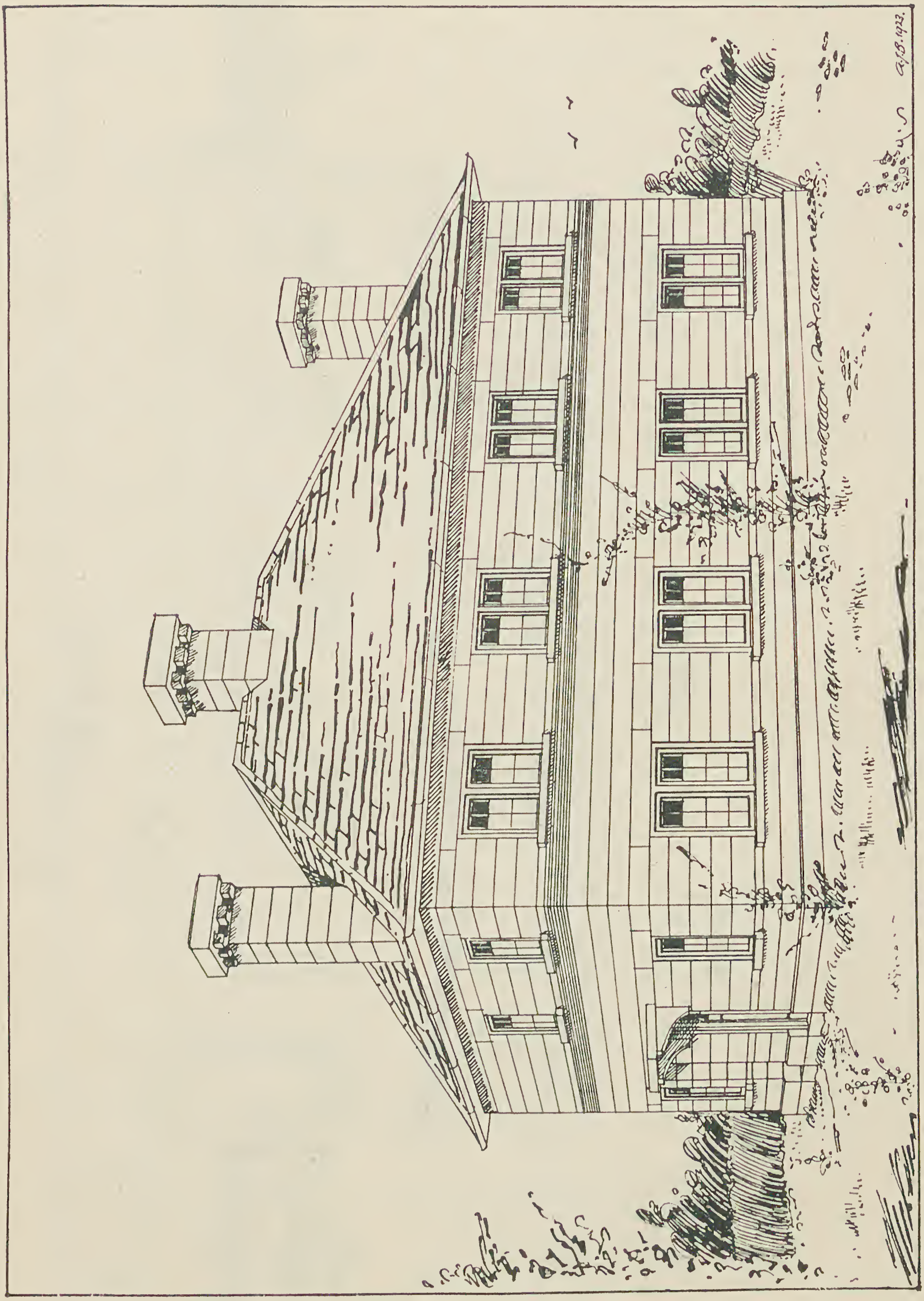


Fig. 21.—Type No. 2: With Pitched Roof.

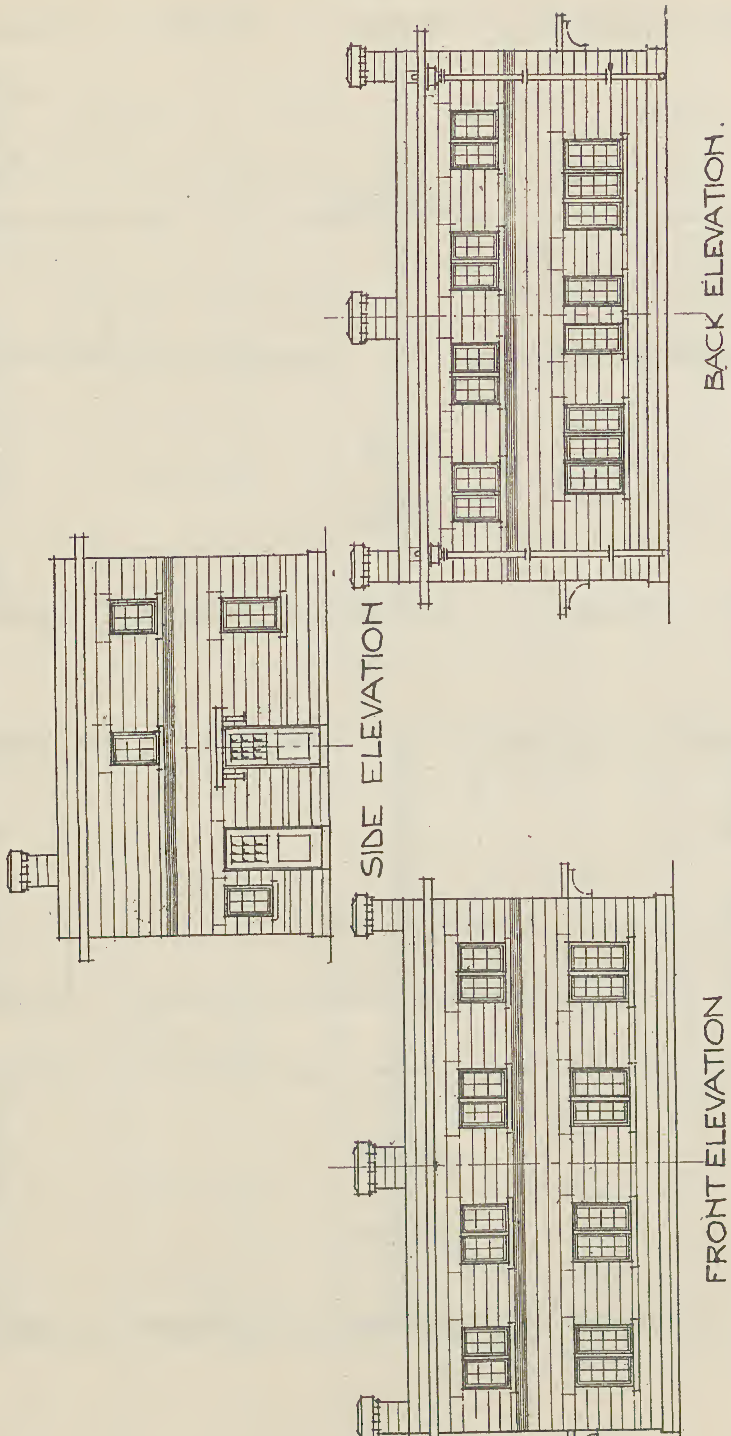
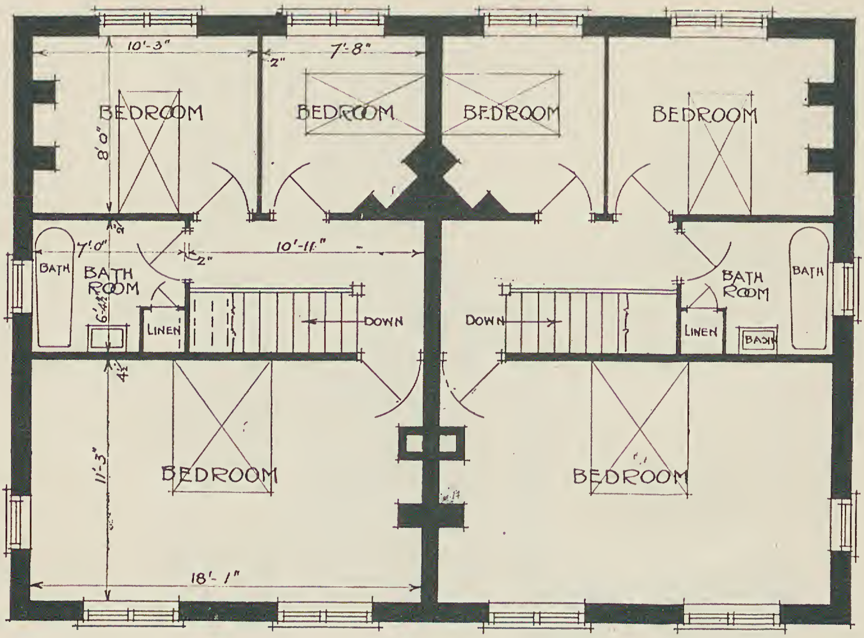
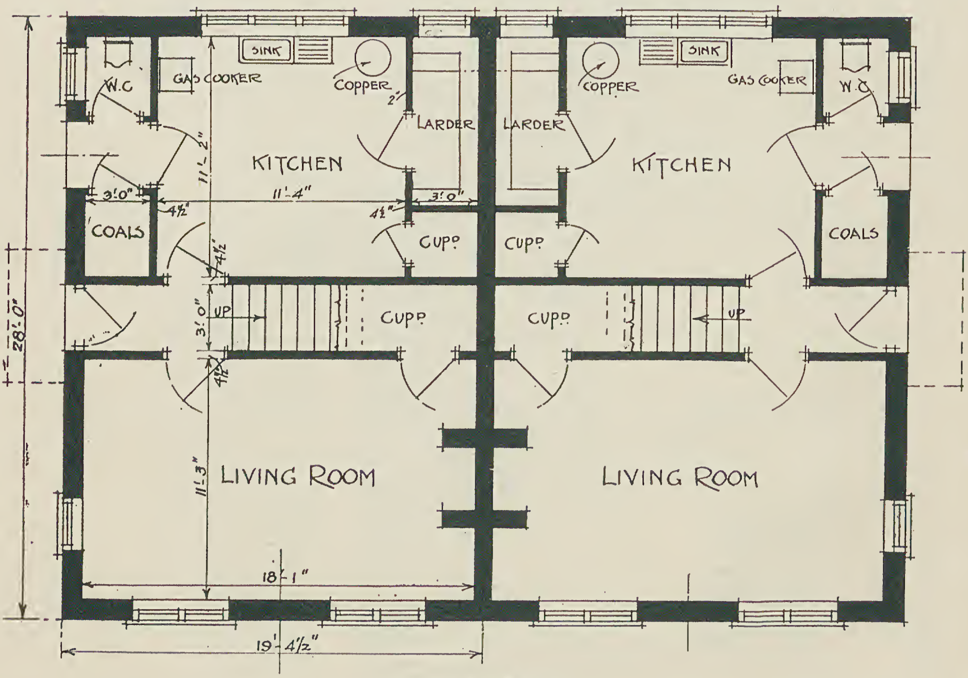


FIG. 22.—TYPE No. 2: ELEVATIONS.



First Floor Plan.



Ground Floor Plan.

Fig. 23.—Type No. 2 : Plans.

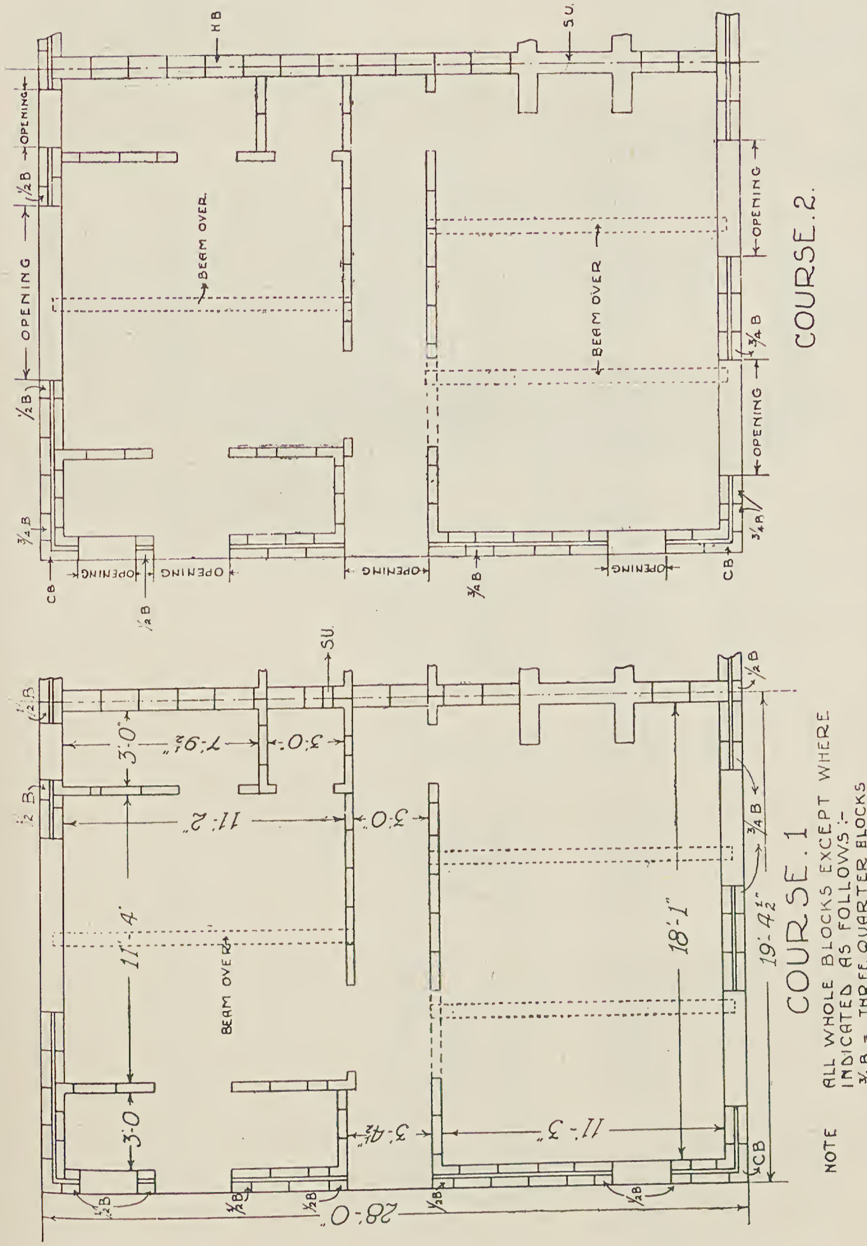


Fig. 24.—Type No. 2: Plans Showing Bonding of Blocks.

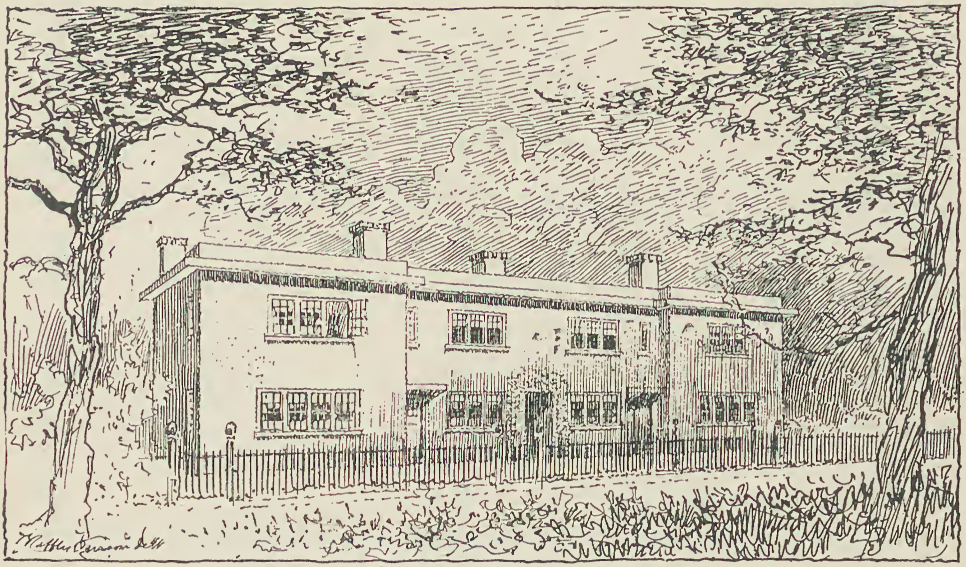


FIG. 25.—VARIATION OF TYPES NOS. 1 AND 2, WITH FLAT ROOF.

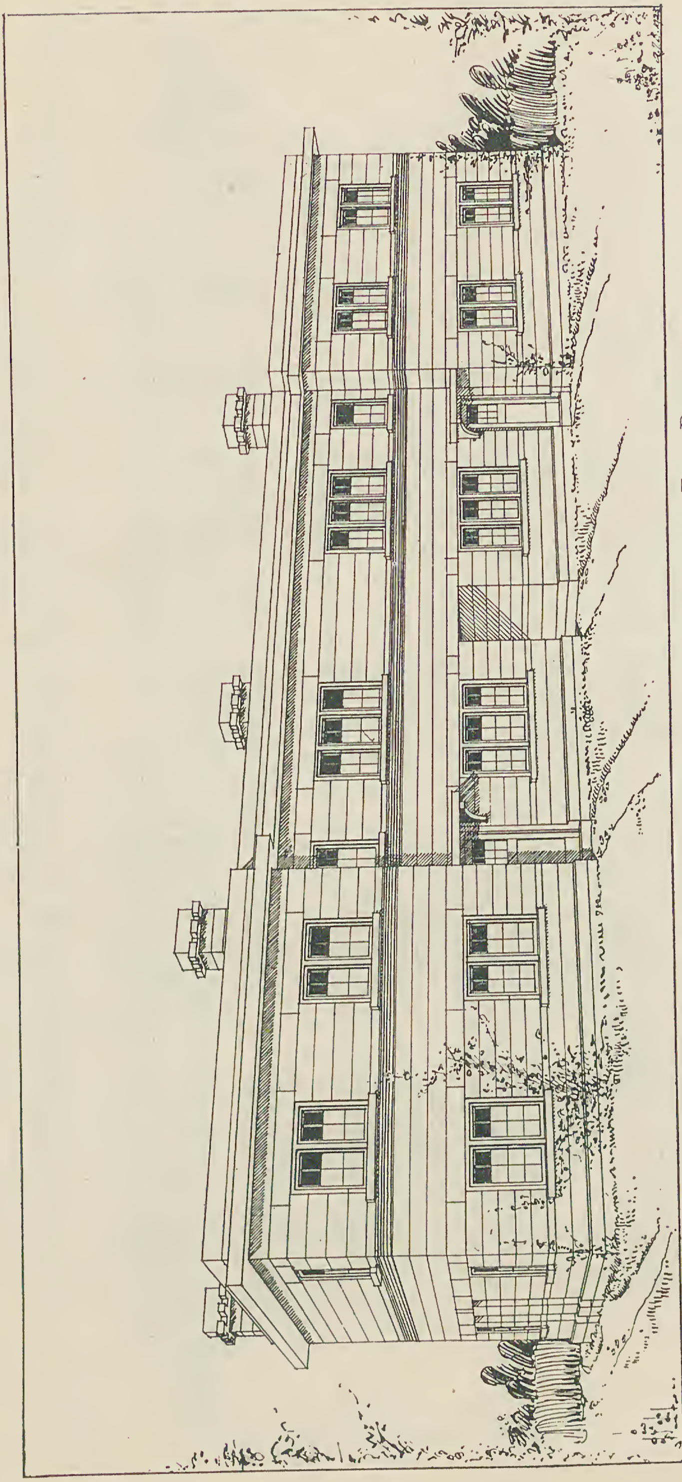


Fig. 26.—Block of Houses, Types Nos. 1 and 2, with Flat Roof.

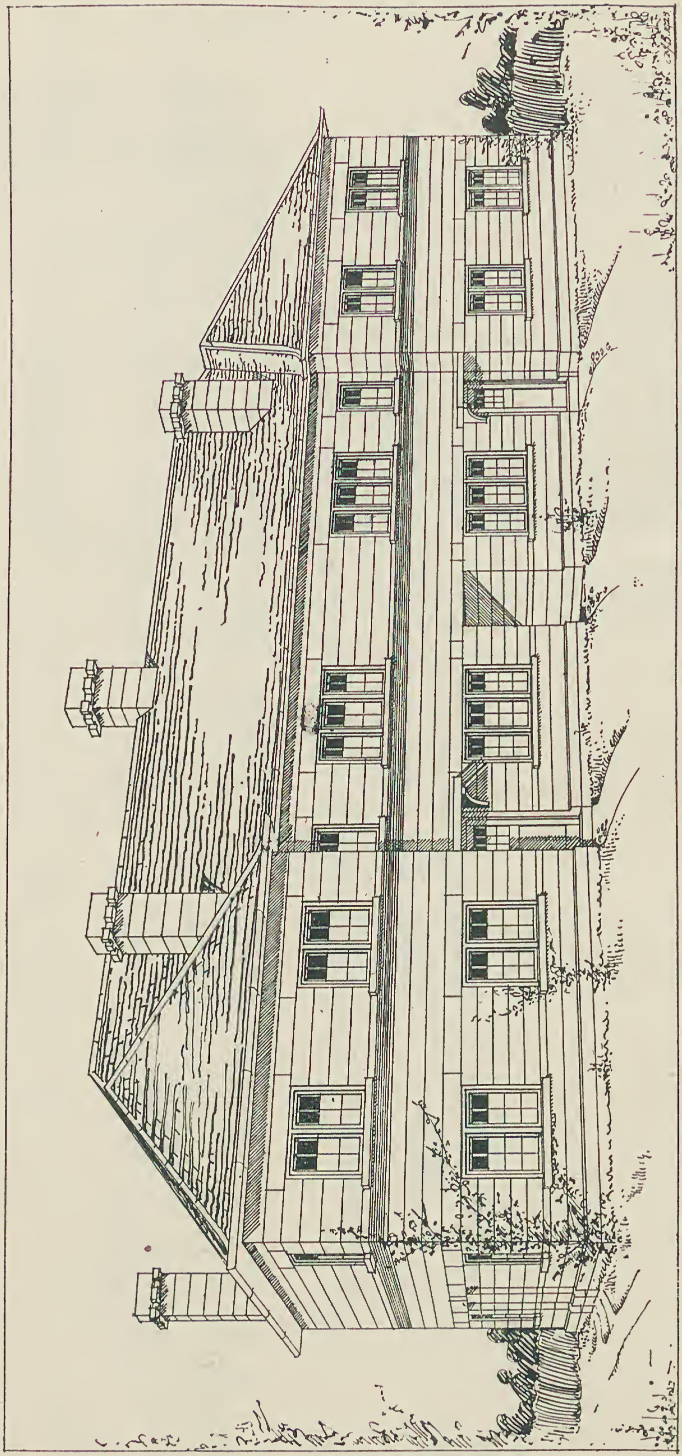


Fig. 27.—Block of Houses, Types Nos. 1 and 2, with Pitched Roof.

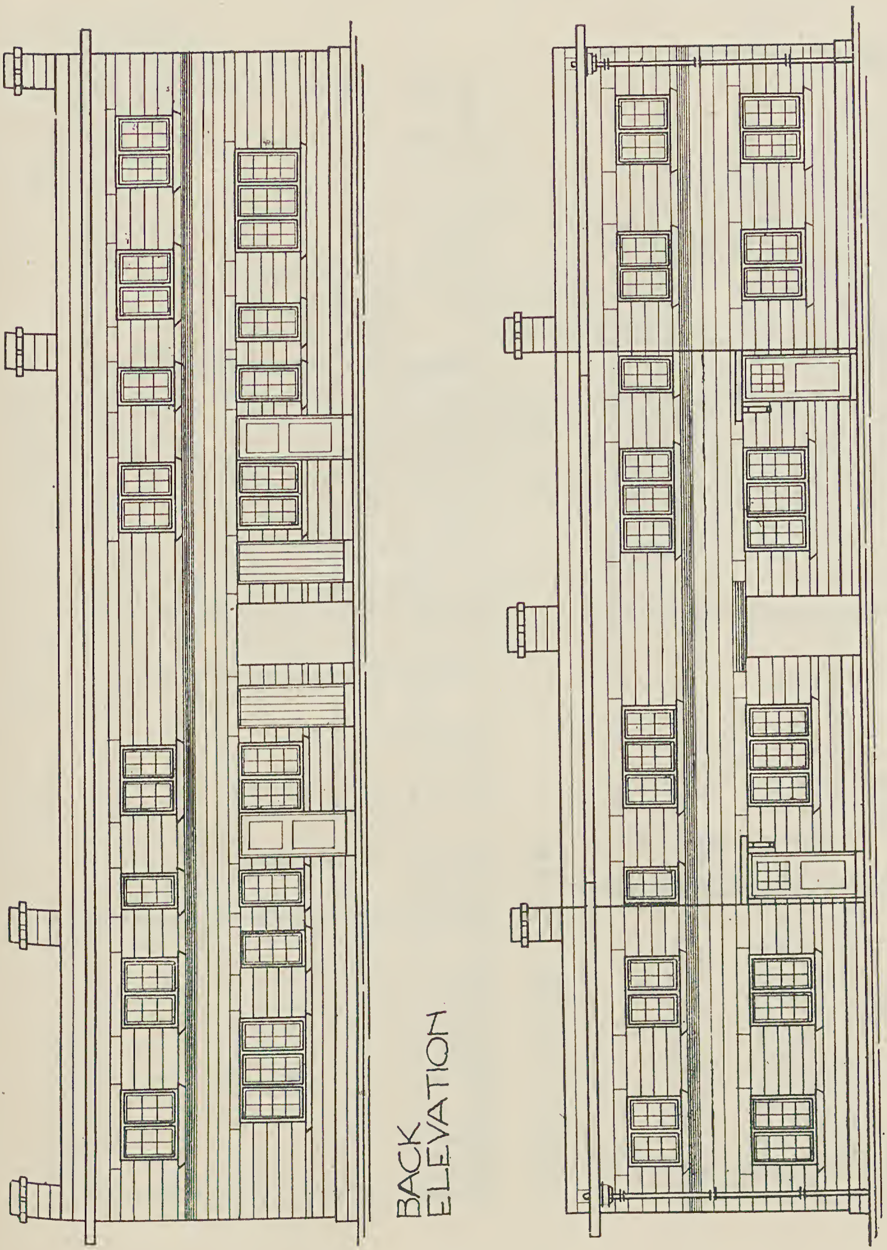


Fig. 28.—Block of Houses, Types Nos. 1 and 2, with Flat Roof: Elevations.

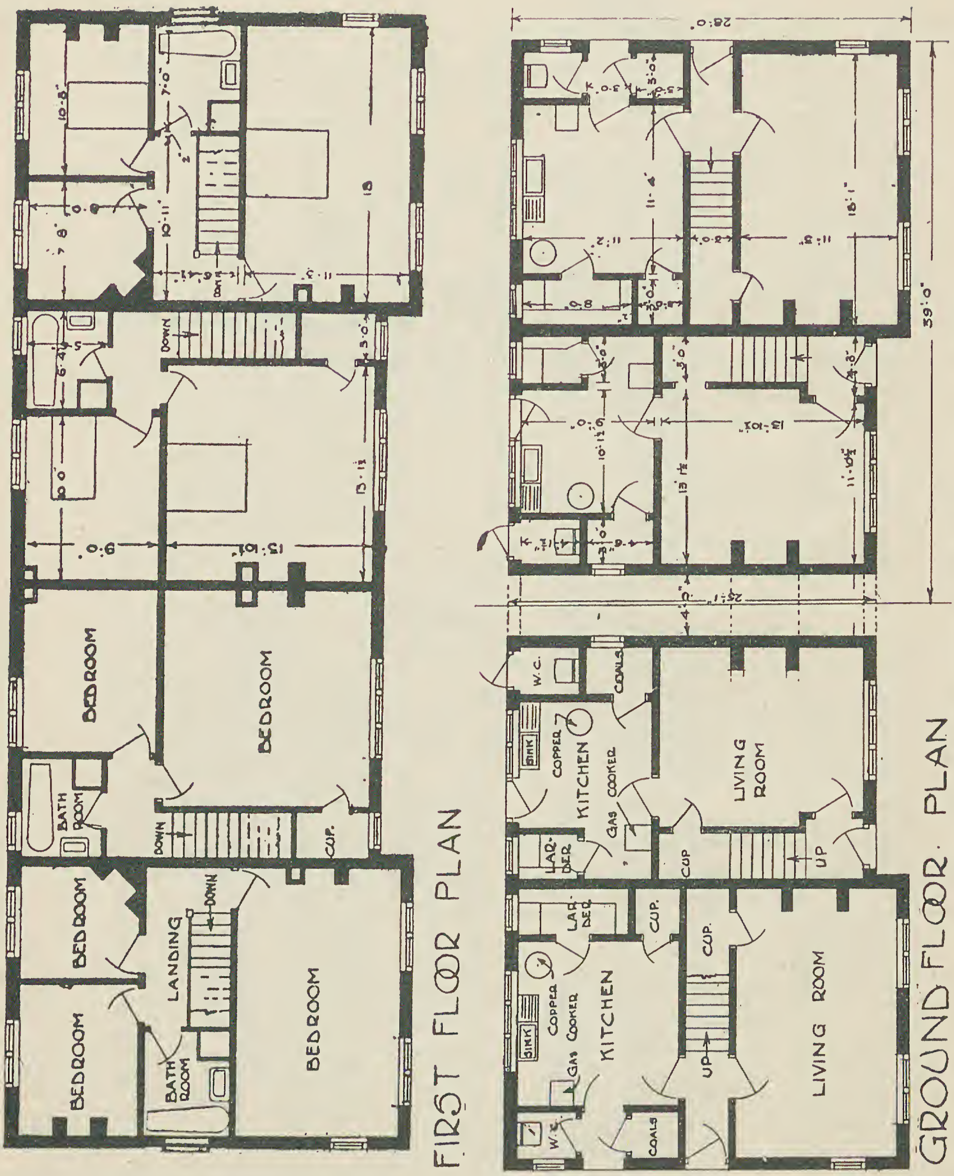


FIG. 29.—BLOCK OF HOUSES, TYPES Nos. 1 AND 2: PLANS.

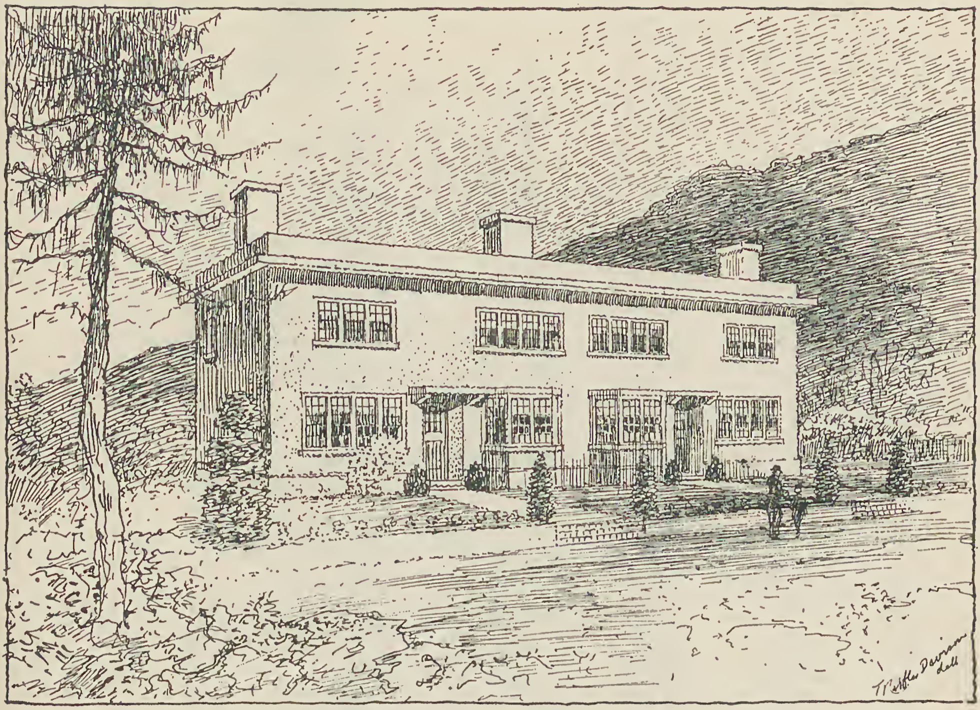


FIG. 30.—TYPE No. 3 : WITH FLAT ROOF.

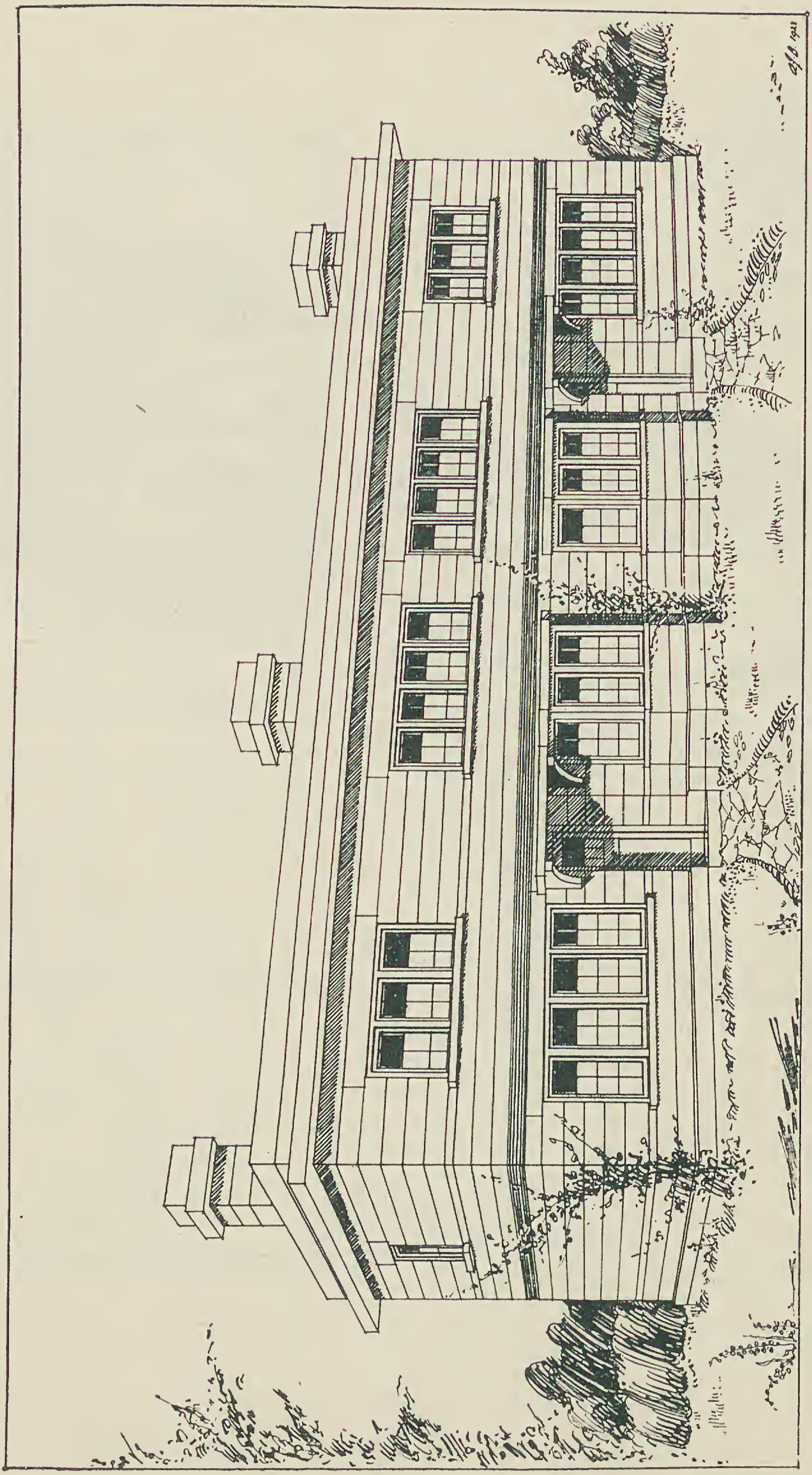


Fig. 31.—Type No. 3: With Flat Roof.

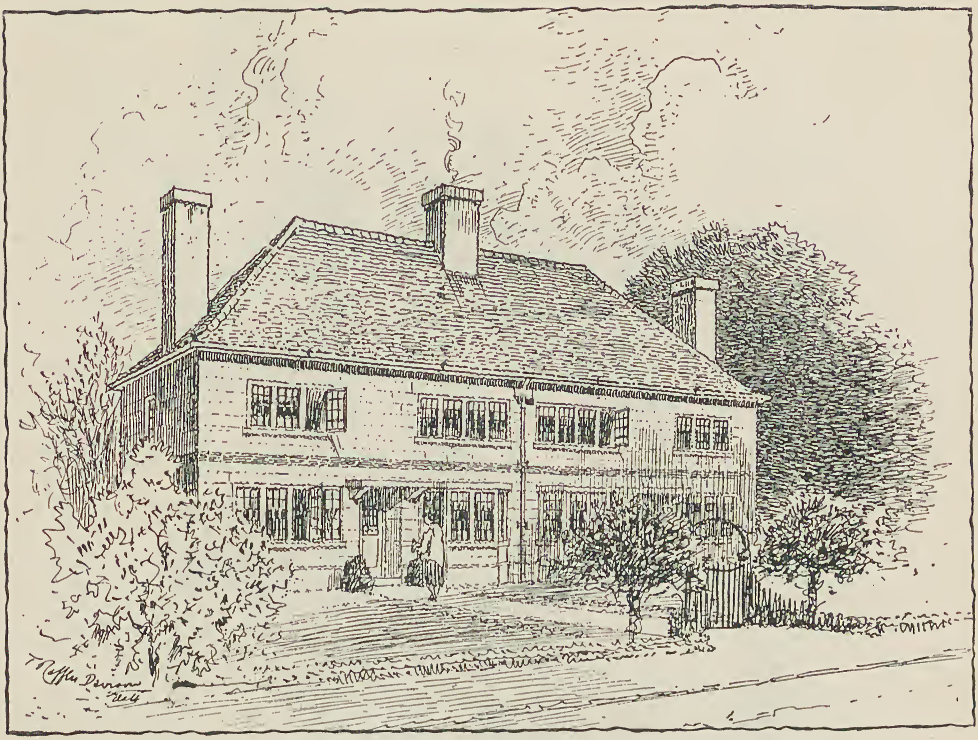


FIG. 32.—TYPE No. 3: WITH PITCHED ROOF.

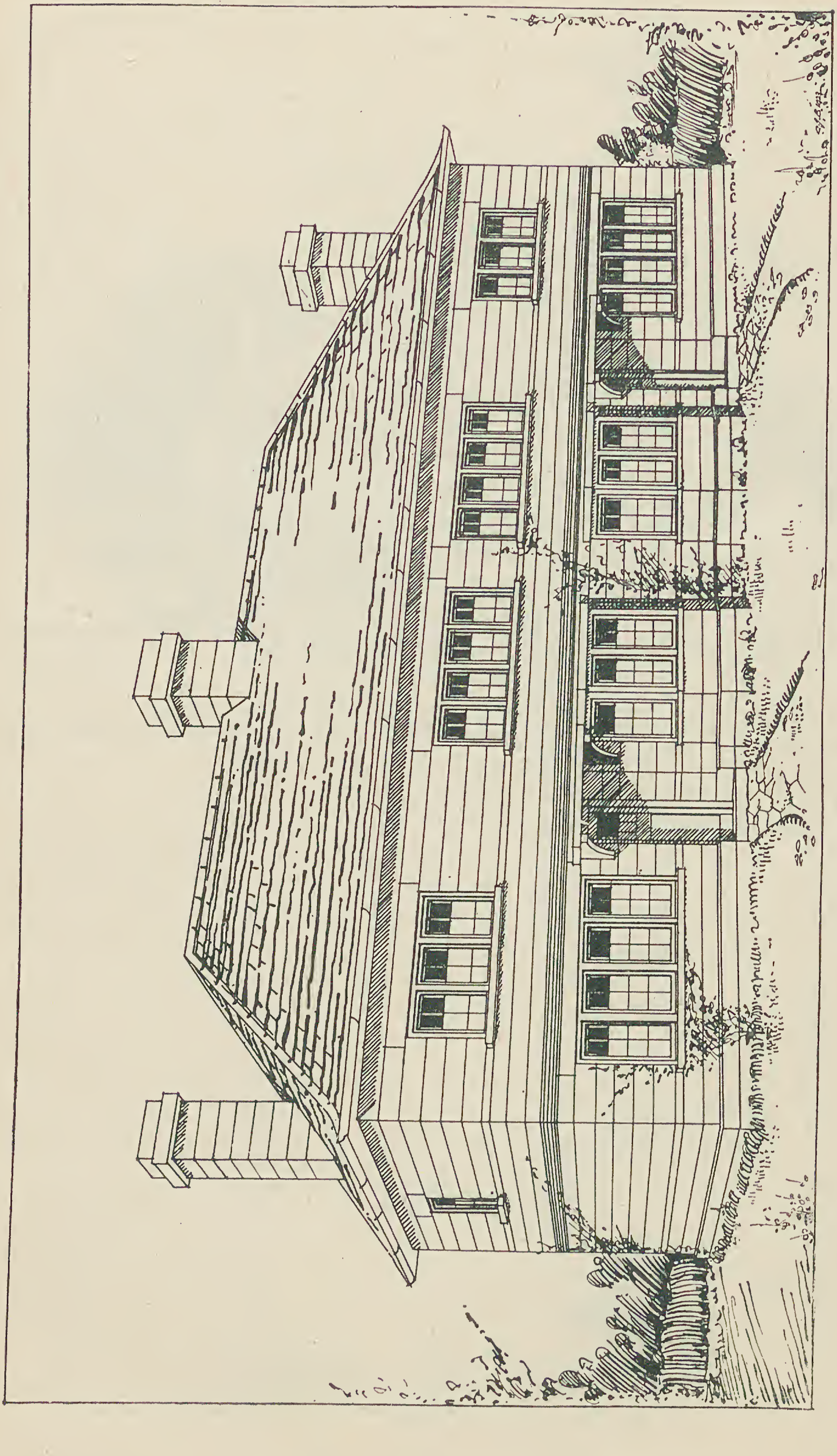
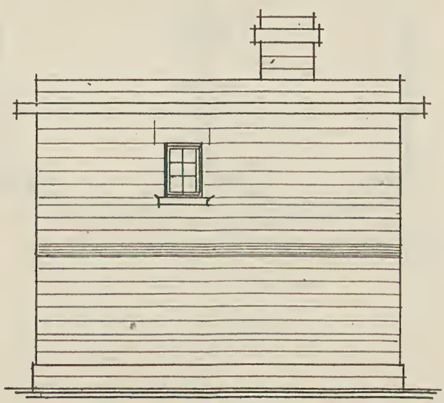


Fig. 33.—Type No. 3: With Pitched Roof.

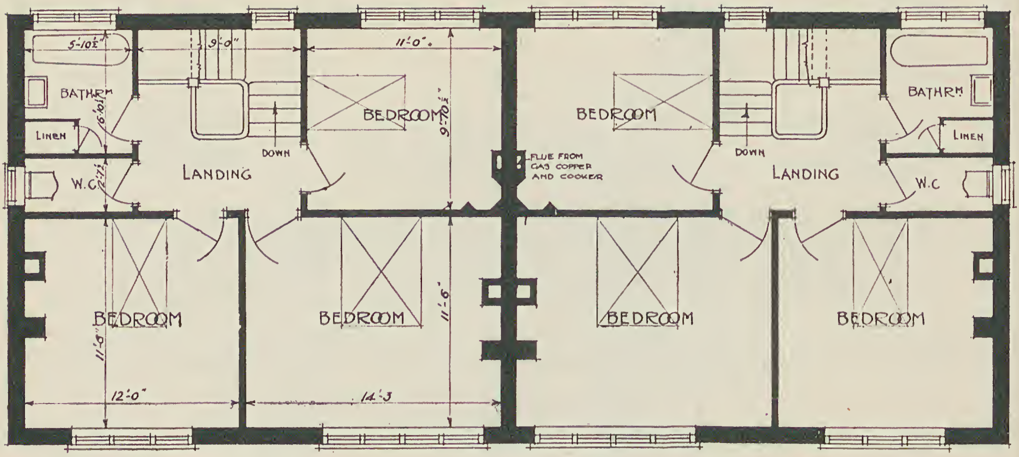
FRONT ELEVATION

BACK ELEVATION

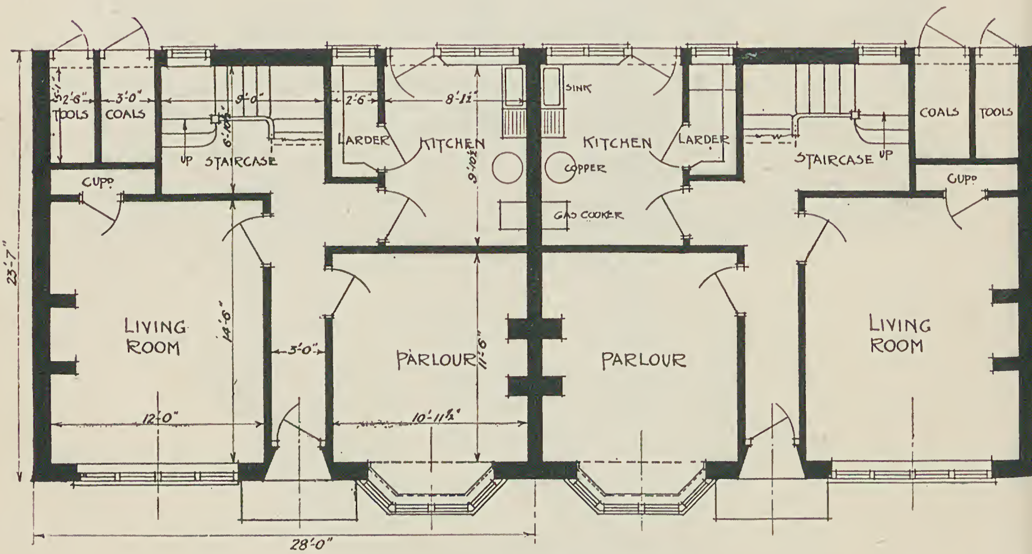


SIDE ELEVATION

Fig. 34.—Type No. 3: Elevations.



FIRST FLOOR PLAN.



GROUND FLOOR PLAN.

FIG. 35.—TYPE No. 3: PLANS.

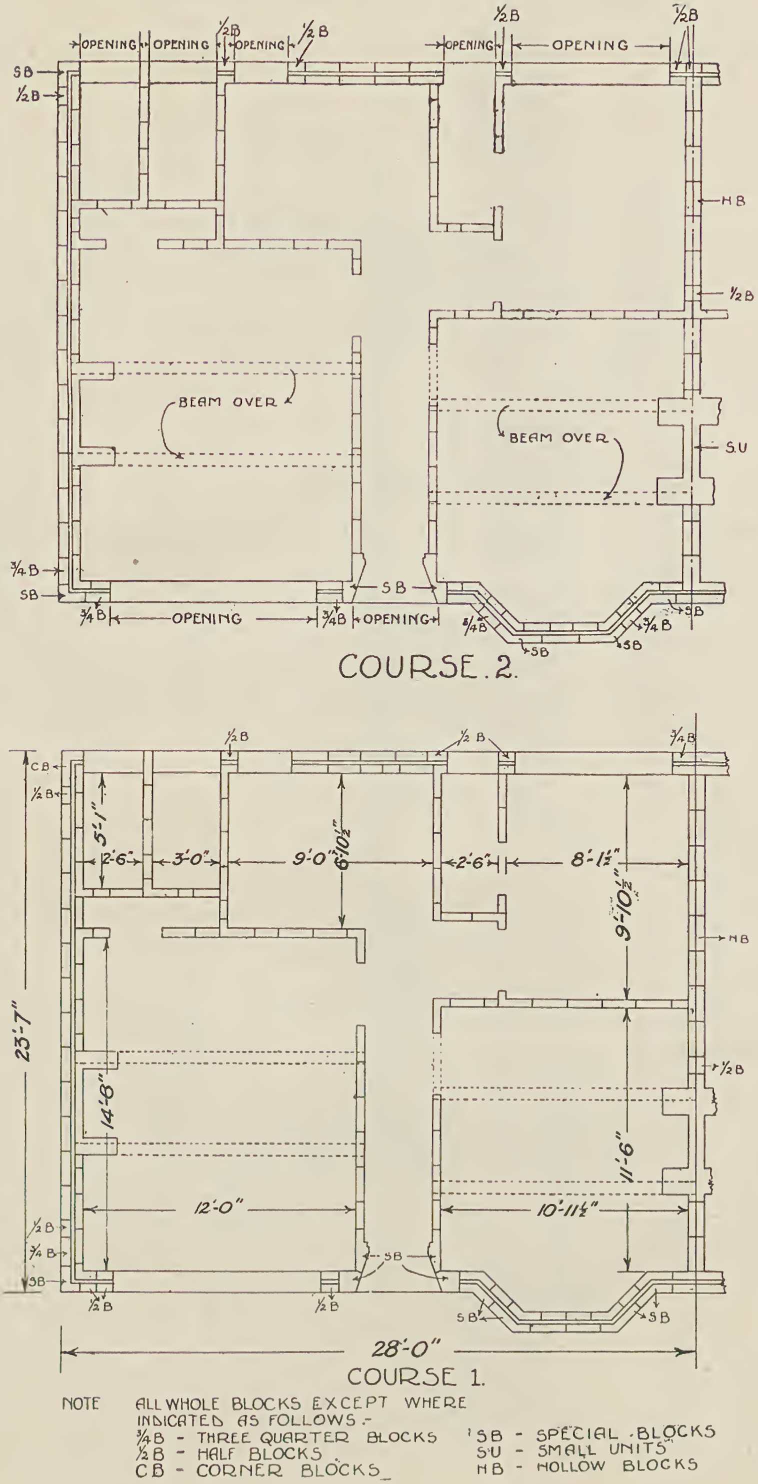


Fig. 36.—Type No. 3: Plans showing Bonding of Blocks.

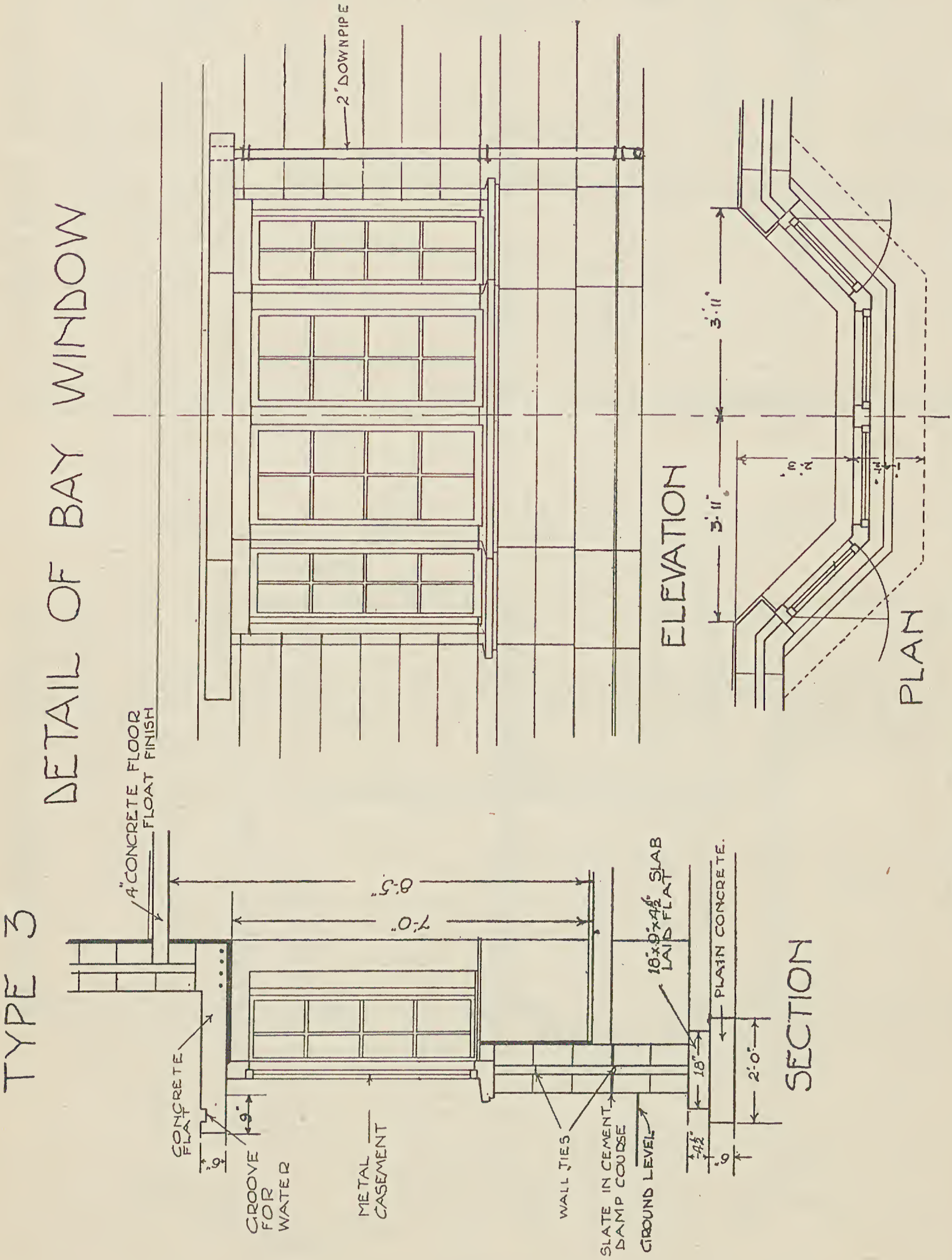


FIG. 37.—TYPE No. 3: DETAIL OF BAY WINDOW.

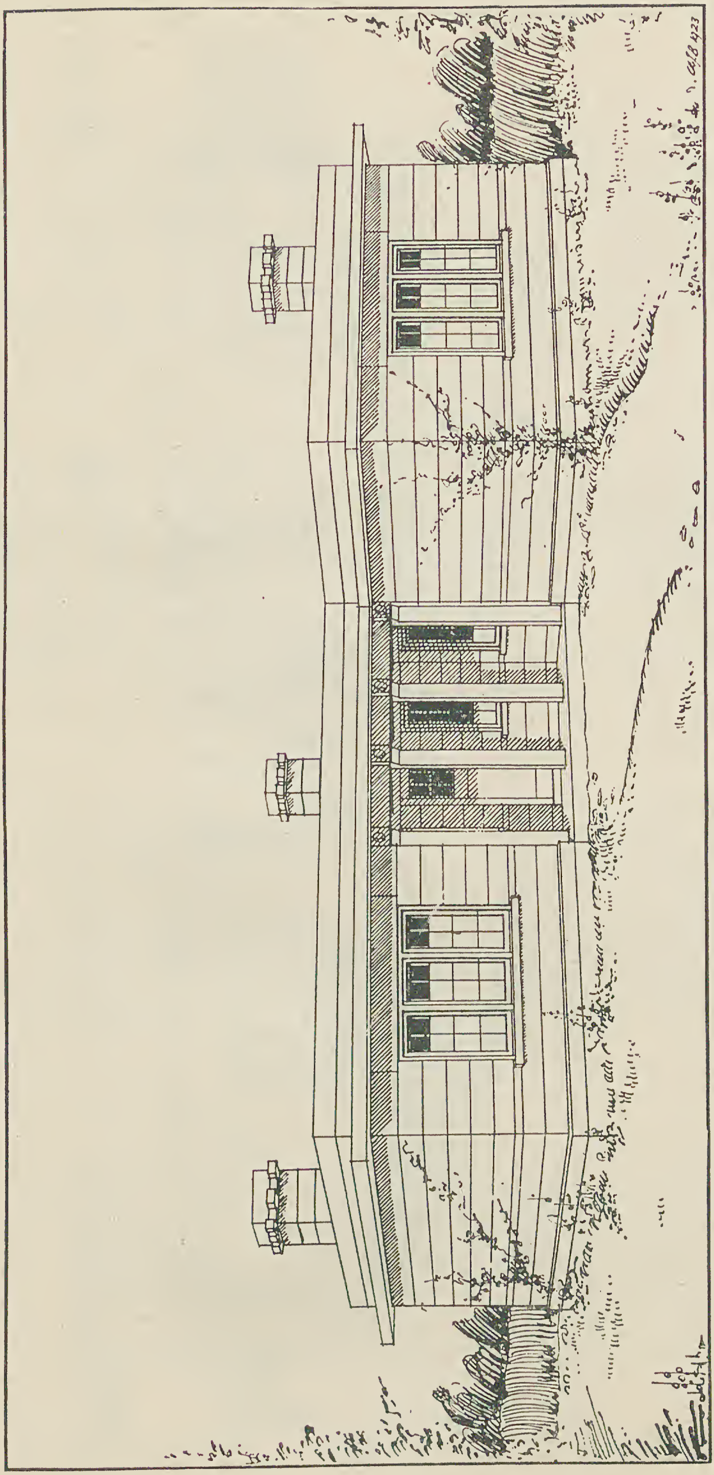


FIG. 38.—TYPE NO. 4: WITH FLAT ROOF.

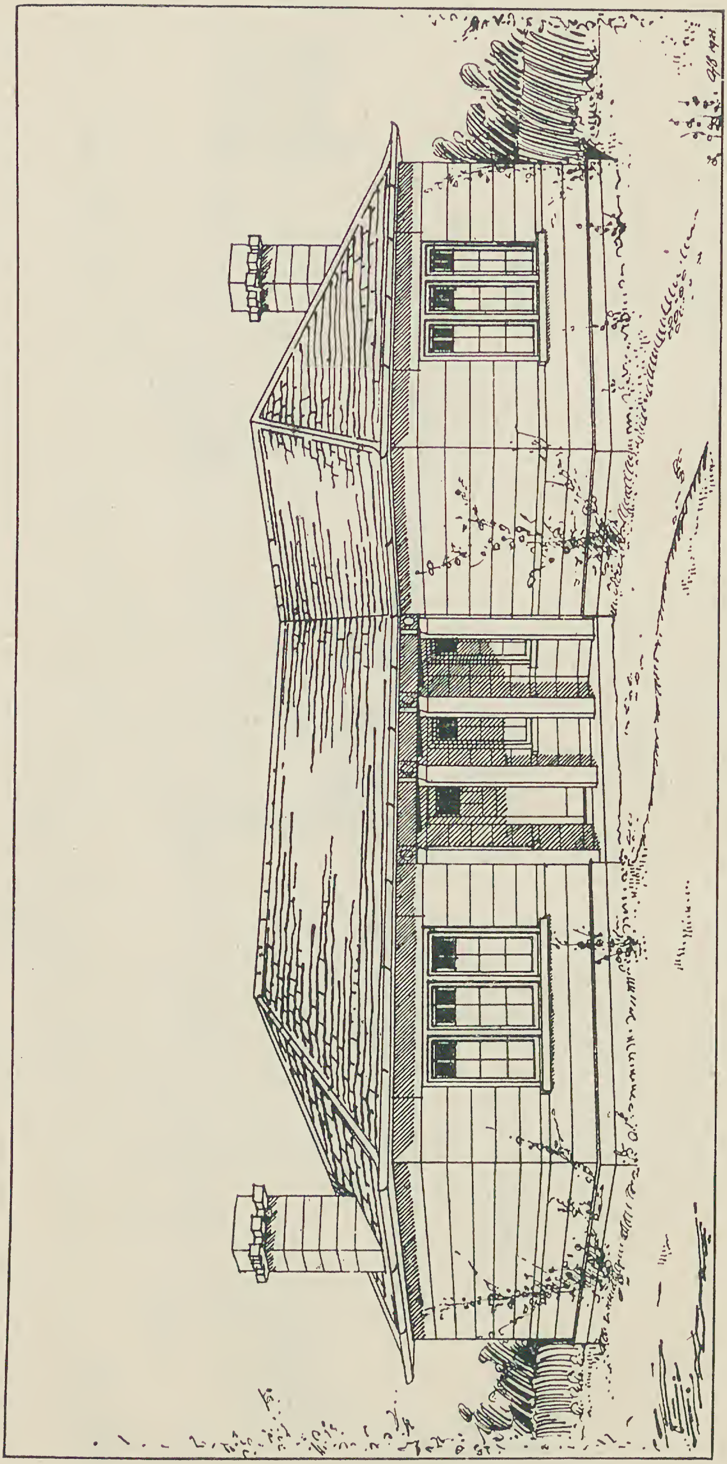


Fig. 39.—Type No. 4: With Pitched Roof.

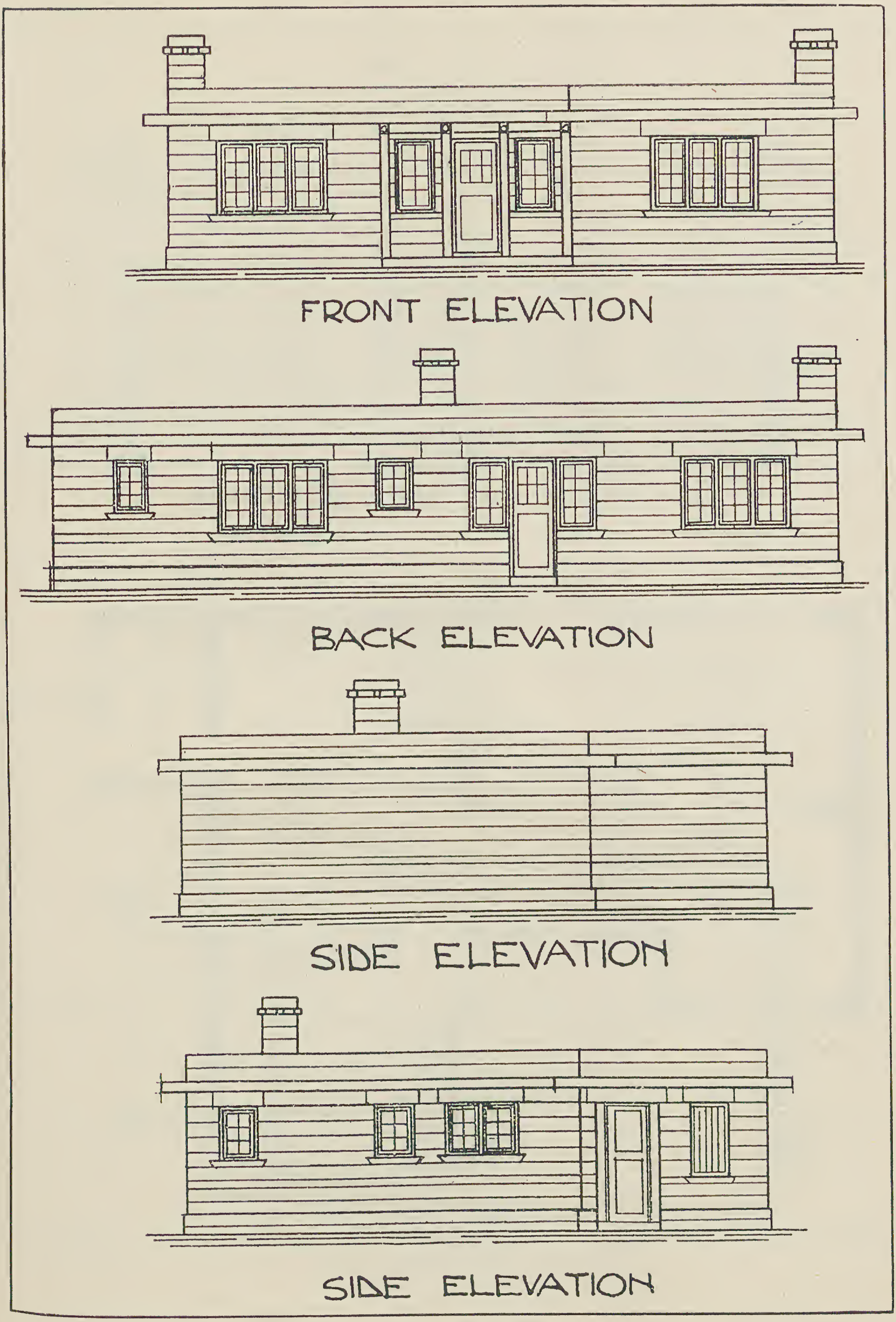


FIG. 40.—TYPE No. 4 WITH FLAT ROOF: ELEVATIONS.

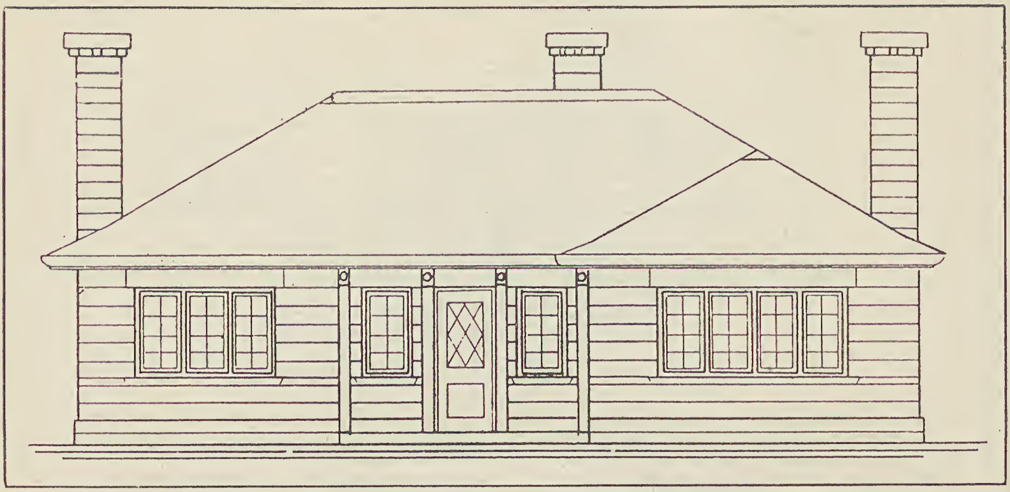


Fig. 41.—Type No. 4 with Pitched Roof : Elevation.

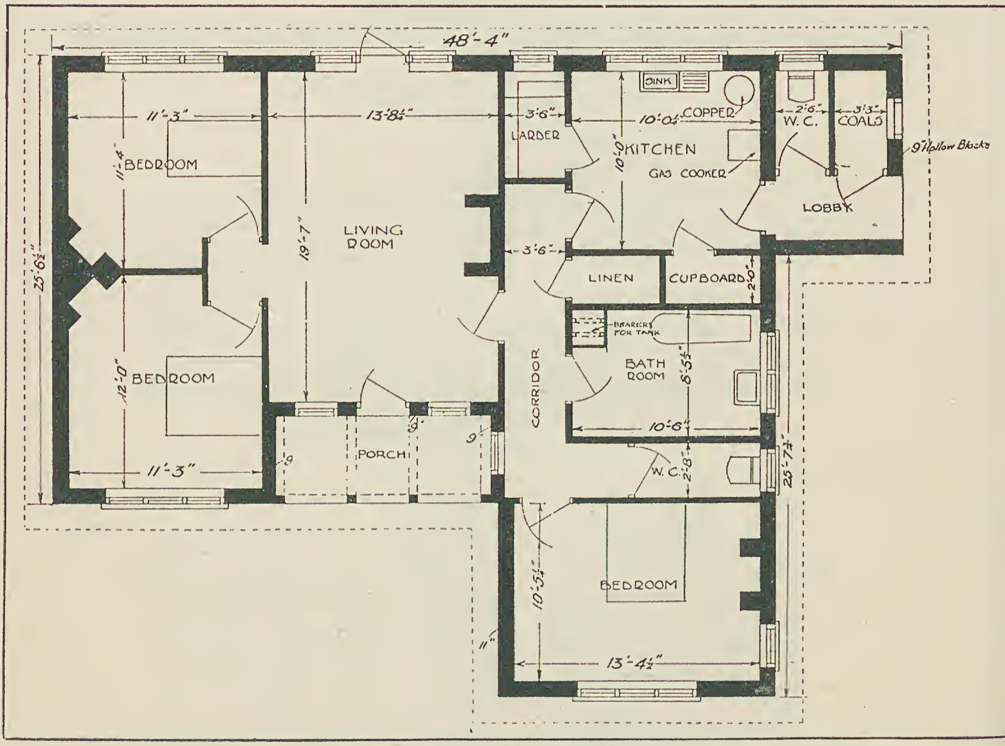


Fig. 42.—Type No. 4 : Plan.

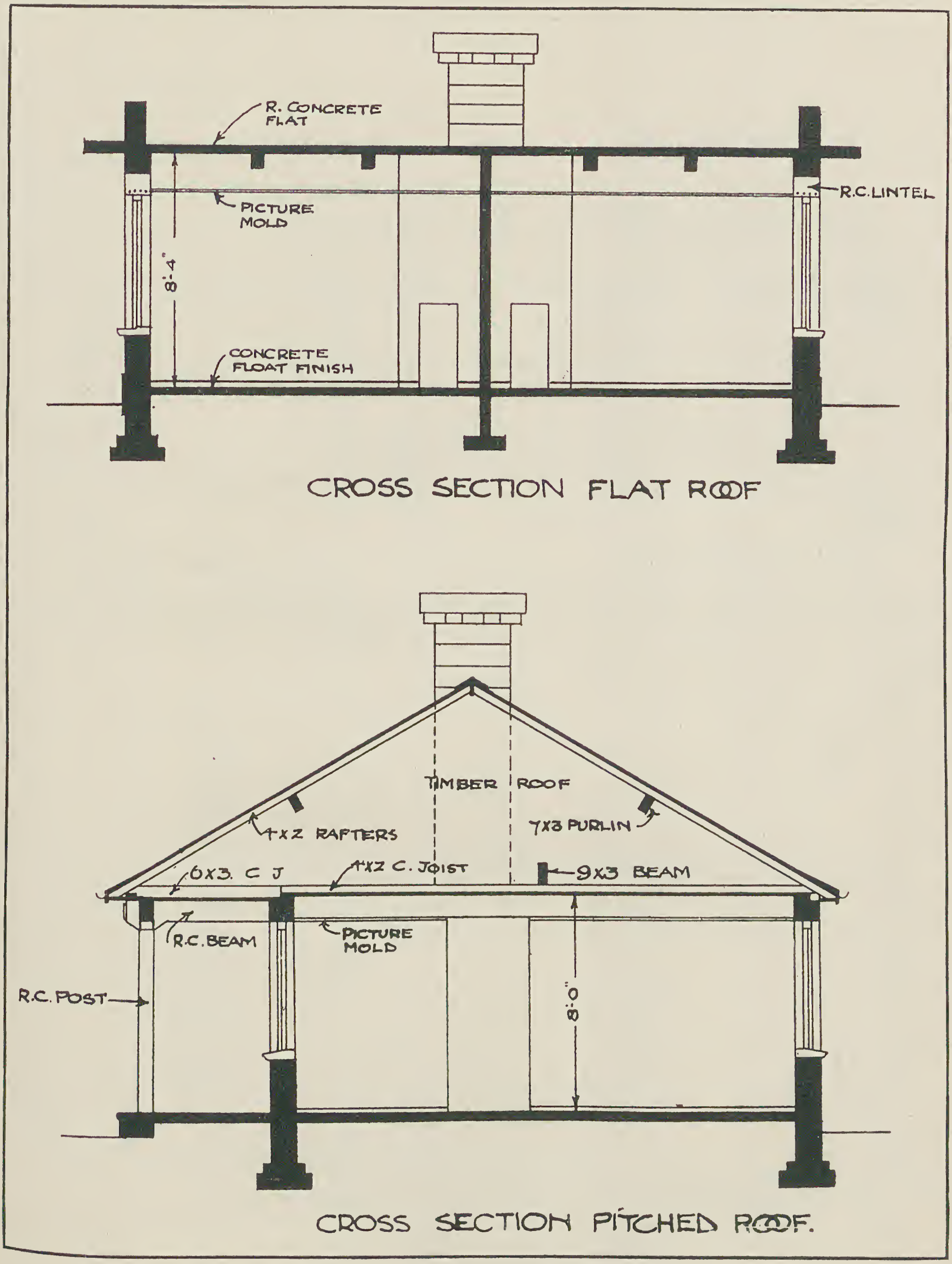


FIG. 43.—TYPE NO. 4: SECTIONS.

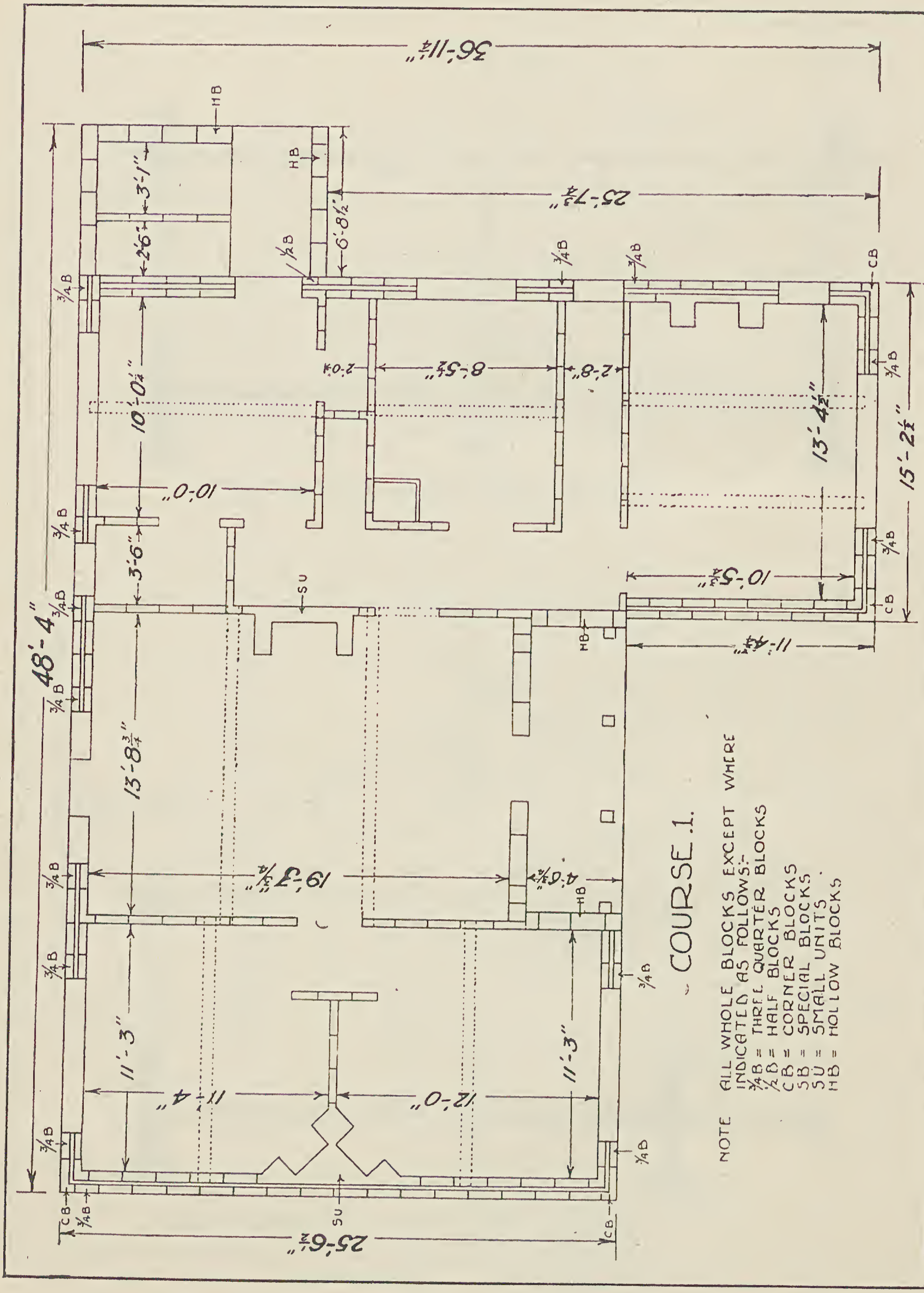


FIG. 44.—TYPE No. 4: PLAN SHOWING BONDING OF BLOCKS.

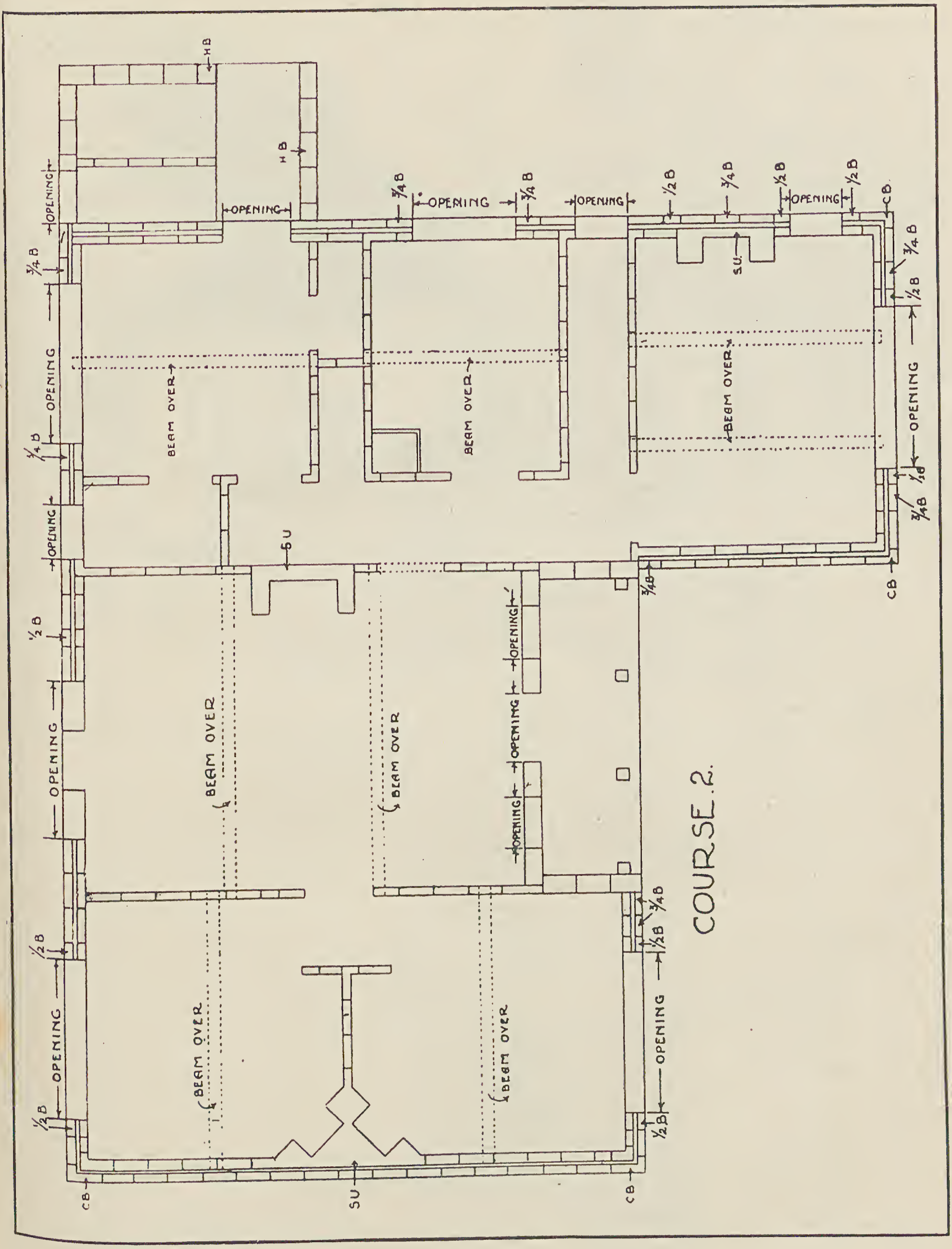


Fig. 45.—Type No. 4: Plan showing Bonding of Blocks.

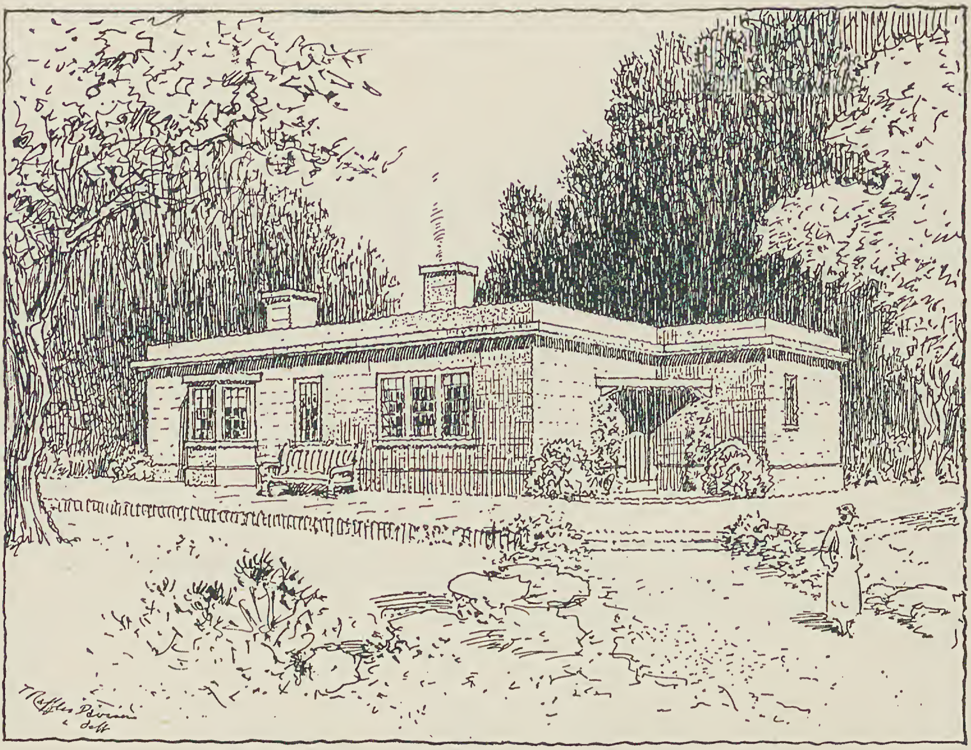


Fig. 46.—Variation of Type No. 5, with Flat Roof.

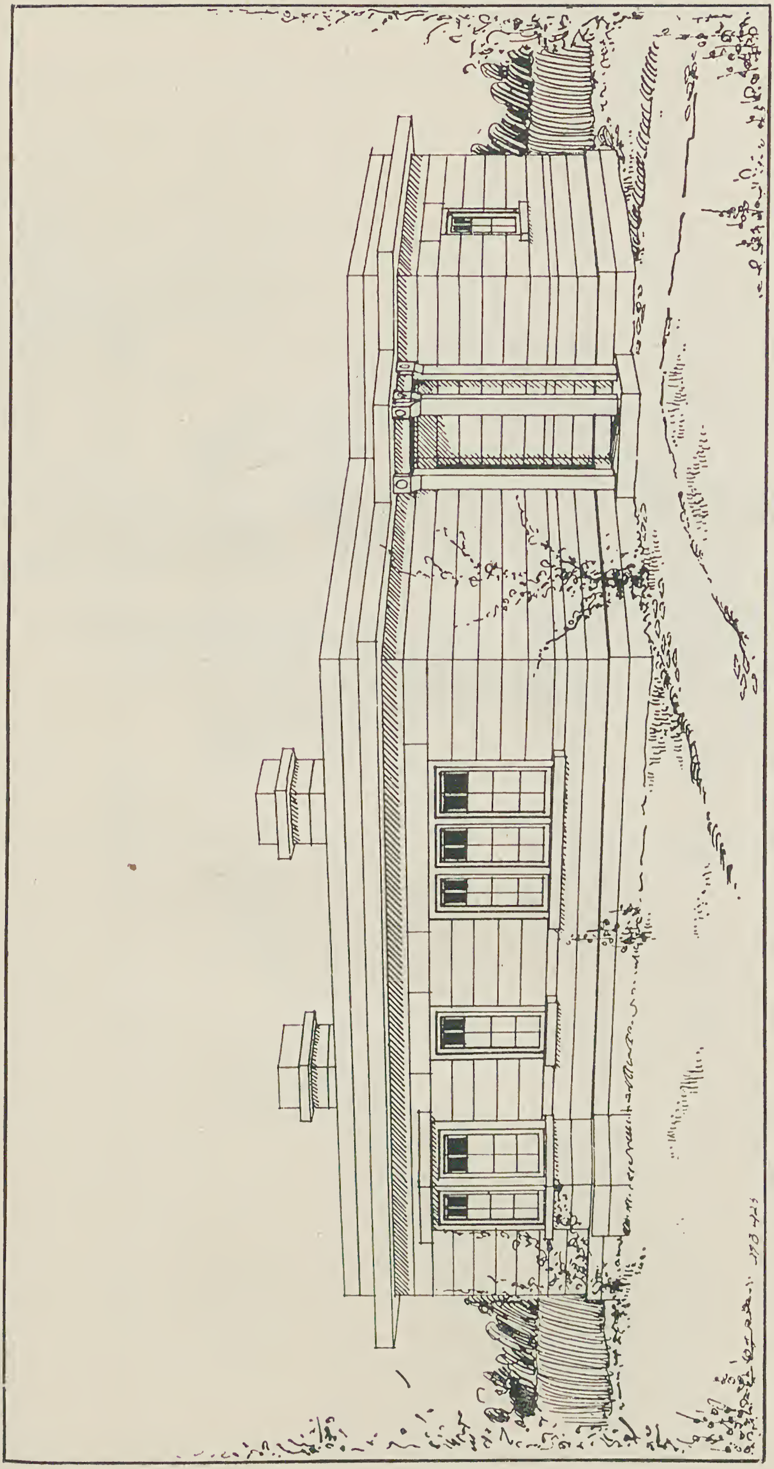


Fig. 47.—Type No. 5: With Flat Roof.

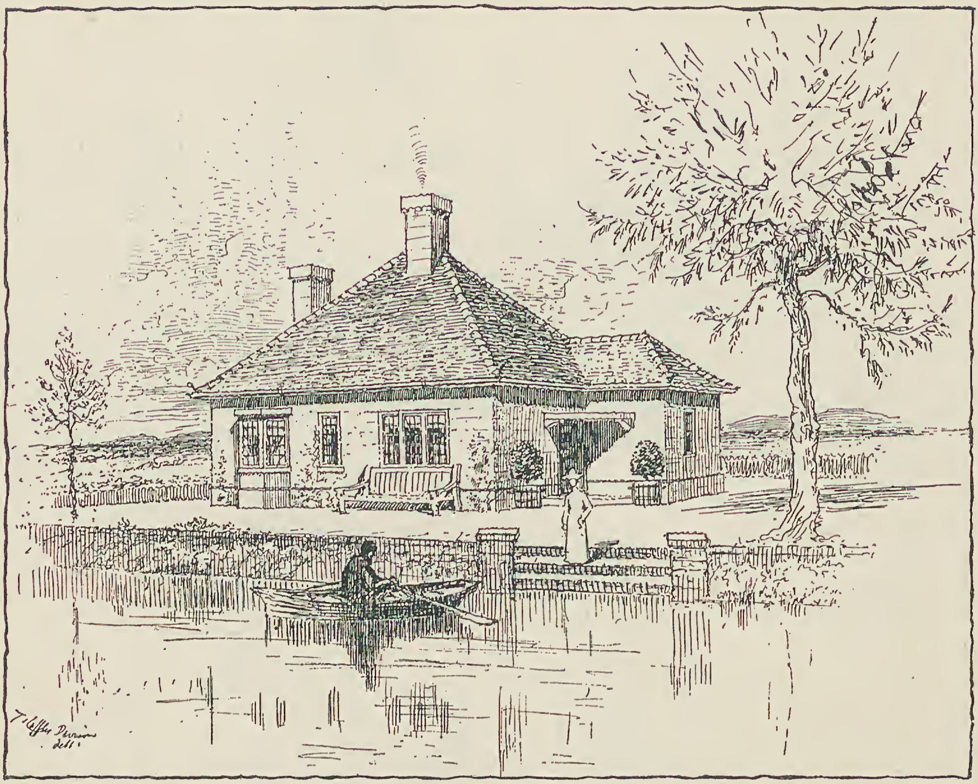


Fig. 48.—Type No. 5: With Pitched Roof.

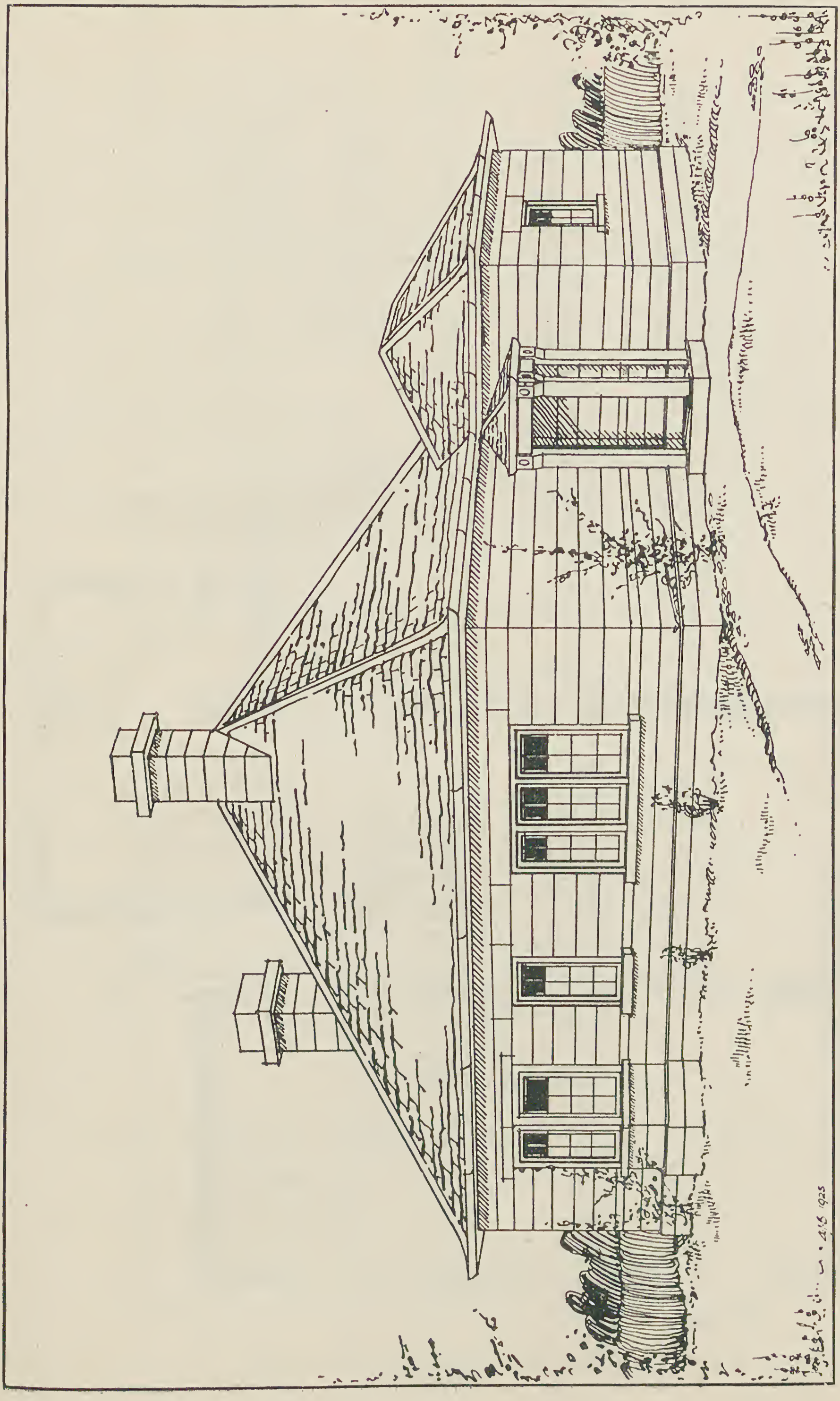


FIG. 49.—TYPE No. 5: WITH PITCHED ROOF.

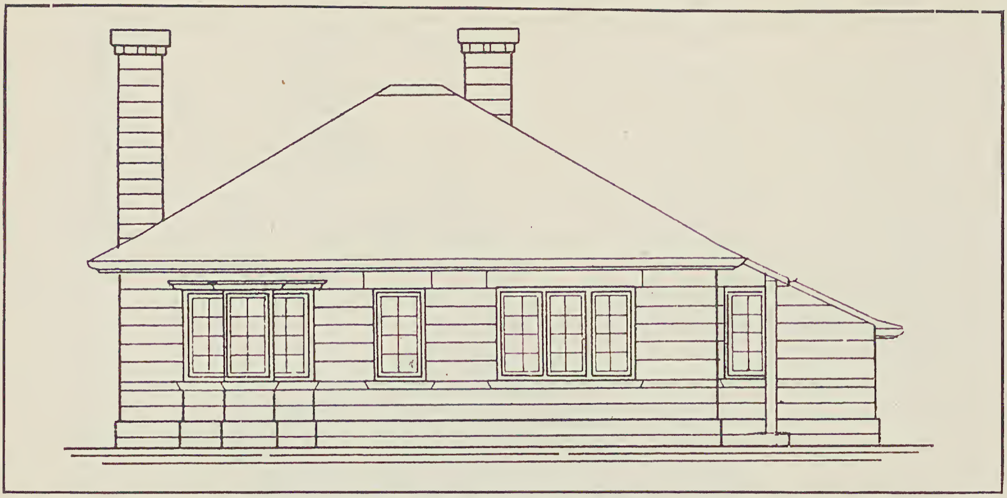


Fig. 50.—Type No. 5: With Pitched Roof.

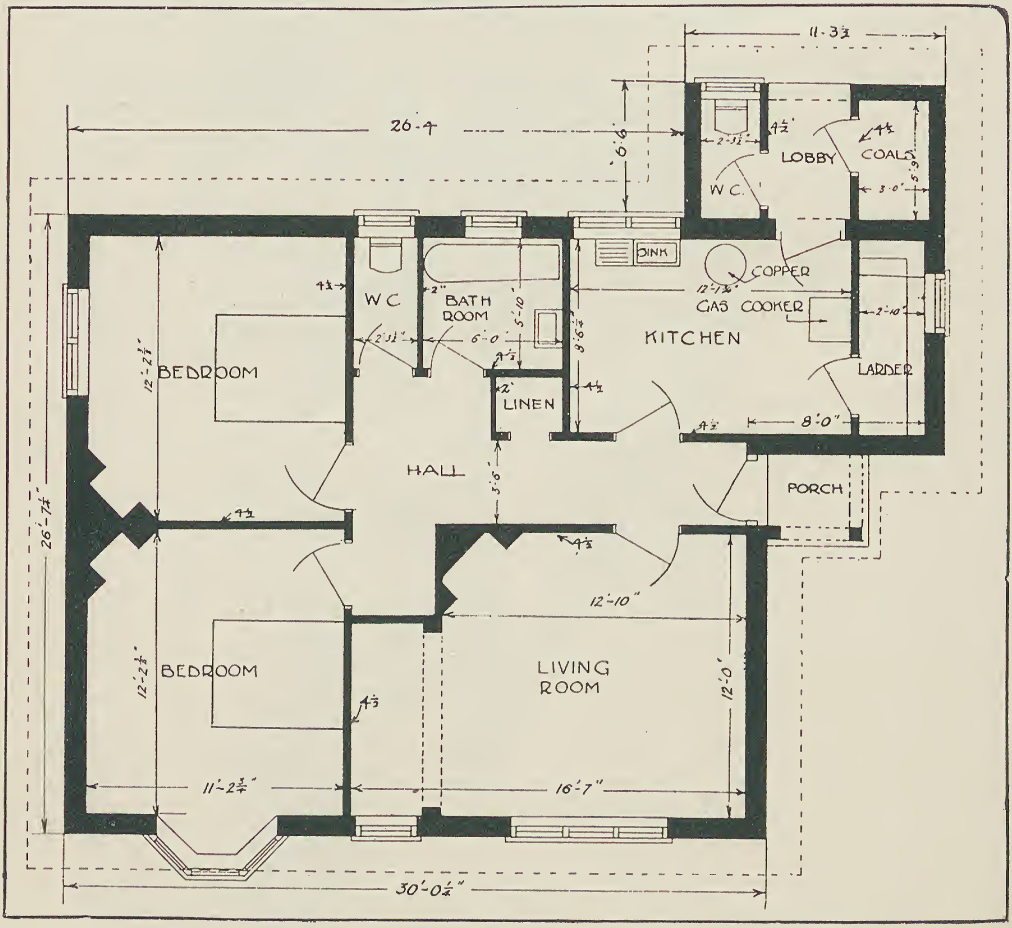


Fig. 51.—Type No. 5: Plan.

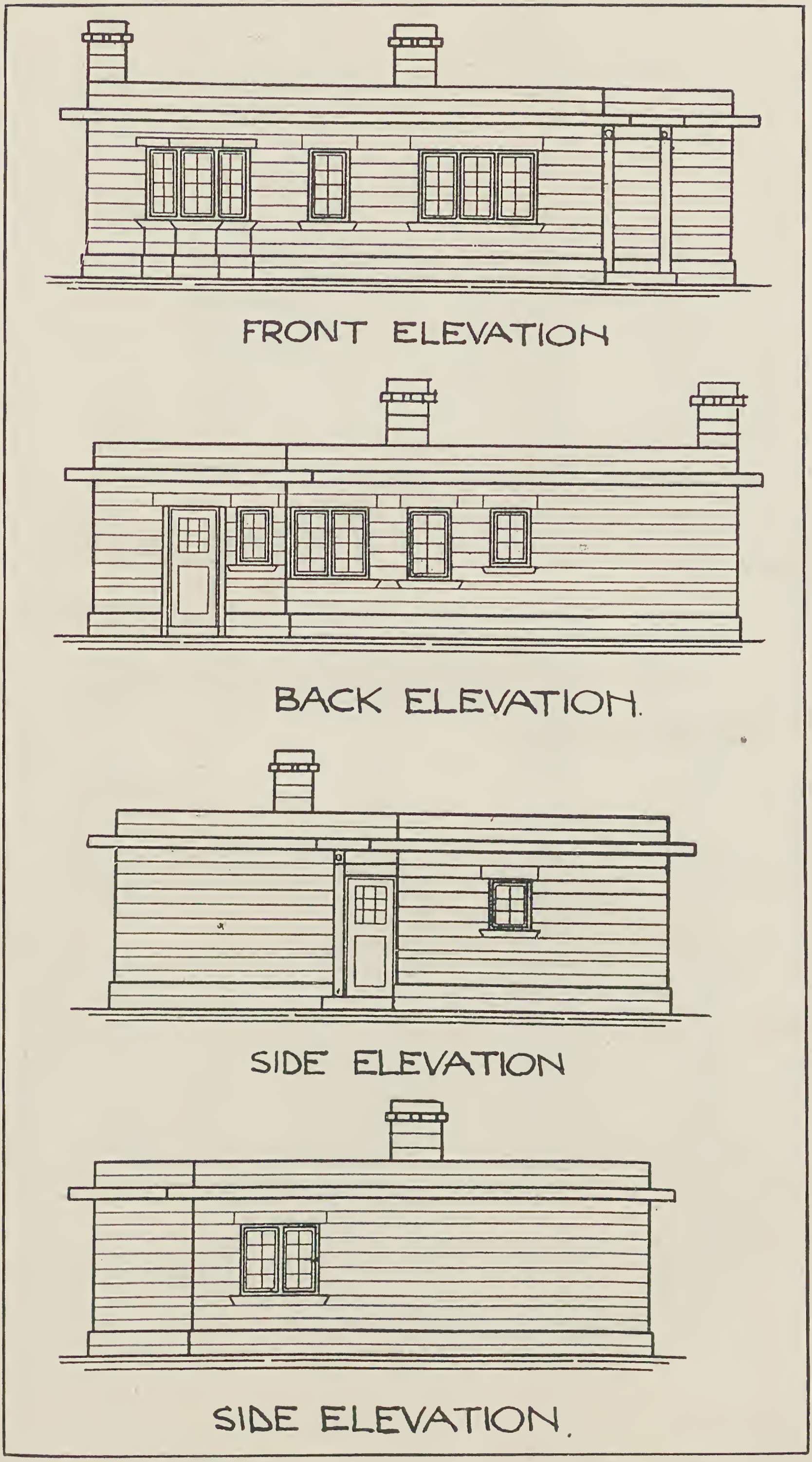


FIG. 52.—TYPE No. 5, WITH FLAT ROOF: ELEVATIONS.

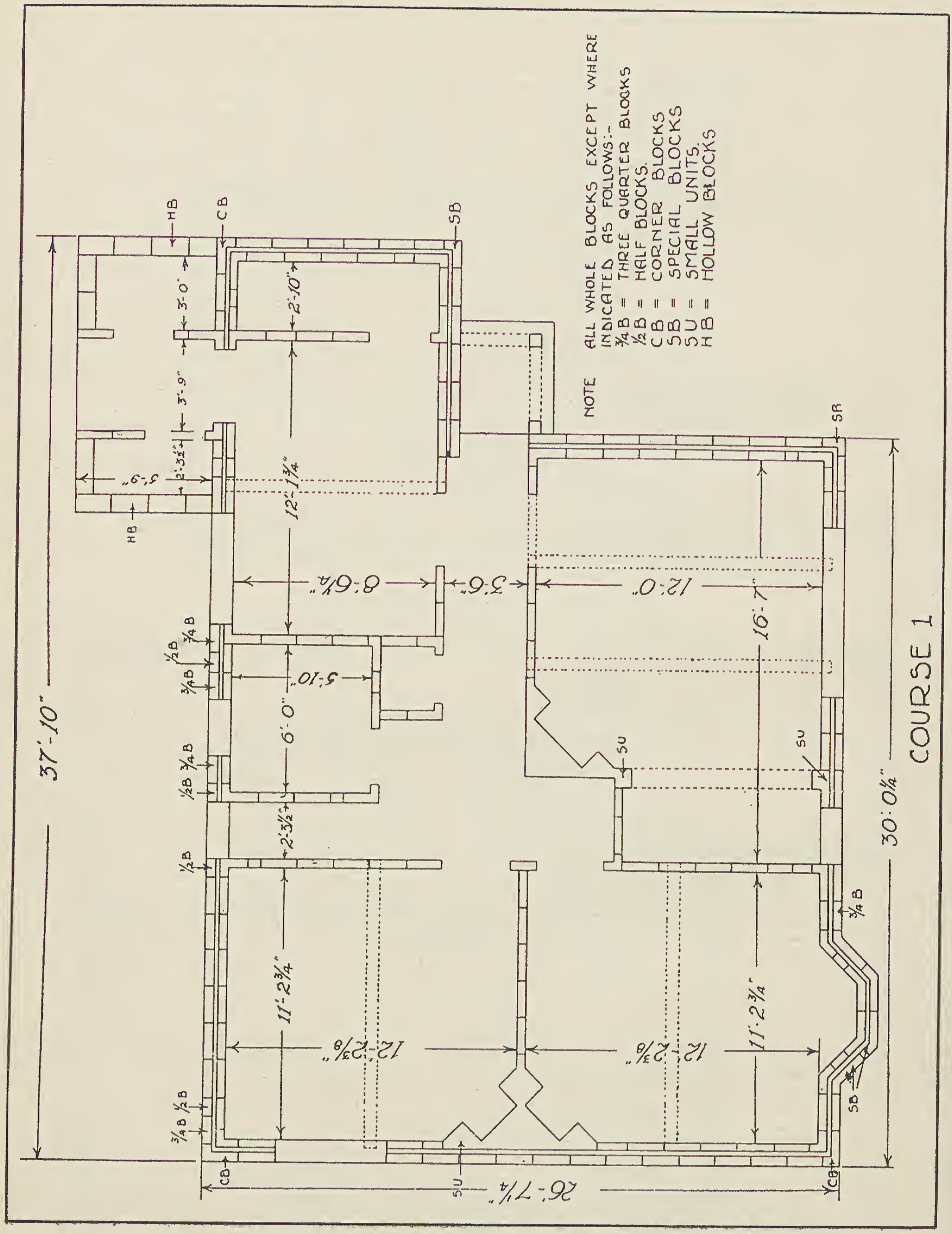


Fig. 53.—Type No. 5: Plan showing Bonding of Blocks.

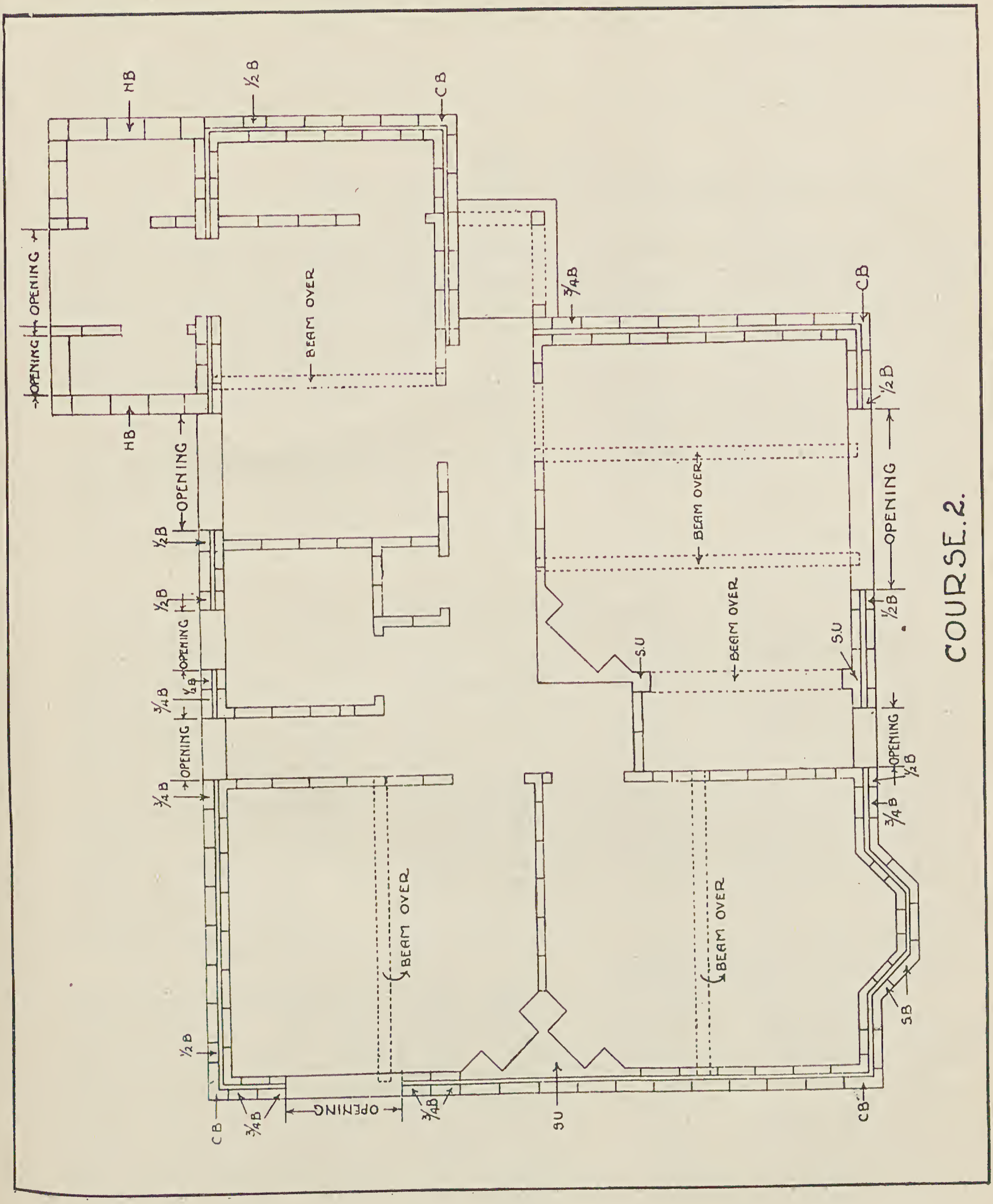


Fig. 54.—Type No. 5: Plan showing Bonding of Blocks.

CHAPTER IV

CAST-IN-SITU CONCRETE CONSTRUCTION

In-situ concrete construction has been used for houses with success, and in some cases is cheaper than precast concrete construction. The chief item in the cost is the shuttering, and cast-in-situ construction is most economical when several houses are to be built so that the shuttering can be used many times. Where many houses of the same size and type are to be built, and the shuttering is economically designed, with proper regard for removal and re-erection, the method is cheap and efficient.

The loads to be carried are so small as to be almost negligible. Reinforcement is not required in the walls for the purpose of carrying loads, but some reinforcement has to be provided to prevent cracks which may occur in large surfaces of thin plain concrete due to the shrinking of the concrete and to changes of temperature.

Foundations for Walls.

Foundations for external and party walls are generally strip footings of plain concrete filled into trenches in the ordinary manner. If the walls are reinforced, the vertical bars should be taken down into the footing, or short lengths of bars should be inserted in the footing before the concrete is deposited, and left projecting upward; the wall reinforcement is fixed to these dowel bars, which ensure a good connection between the wall and the foundation.

If the ground is weak the width of the footing has to be increased, in which case the width and the thickness should be determined in the manner described in Chapter II for foundations for concrete block walls. The thickness of the footing can be reduced if transverse reinforcement is provided at the bottom, but, other than in exceptional cases, it is cheaper to provide a plain concrete footing of the required thickness.

Consider a footing 1 ft. 6 in. wide supporting a 9-in. wall and bearing on the ground the safe pressure on which is $1\frac{1}{2}$ tons per square foot. The foundation can carry a load of $1\frac{1}{2} \times 1\frac{1}{2} = 2\frac{1}{4}$ tons per foot length of wall, which is comparable with the average load per foot from the party wall in the pair of houses (Type No. 1) illustrated in *Fig.* 17. If the ground can safely bear only $\frac{3}{4}$ ton per square foot, to carry about 2 tons the footing must be made 2 ft. 9 in. wide. The projection of the wider footing from the face of the 9-in. wall is 12 in. and the smallest thickness for the footing is therefore 12 in., or to comply with certain by-laws one-and-a-third times 12 in., that is 16 in. If the wall is built monolithically with the footing, as is the case in cast-in-situ construction, the thickness can be reduced to 8 in. if 1 : 2 : 4 concrete is used and if $\frac{5}{16}$-in. bars are placed transversely at 6-in. centres 1 in. above the bottom of the footing. Larger

bars at wider spacing cannot be used owing to the short length available for bonding the transverse bars to the concrete in the footing. If a reinforced concrete footing is used it is advisable to lay a smooth layer of lean concrete, called "blinding," 1 in. thick, on the bottom of the excavation before placing the reinforcement, which should be kept about 1 in. clear of the blinding. A design for a typical reinforced concrete footing for a cast-in-situ wall is shown in *Fig.* 55.

If the bearing capacity of the ground differs along the length of the foundation, reinforcement placed longitudinally near the bottom of the footing may be necessary to enable the footing (with or without the assistance of the lower part of the wall) to span over the weaker areas, and to distribute irregular loads from the walls more or less uniformly on the ground. The smallest amount of such longitudinal reinforcement is four $\frac{3}{8}$-in. bars placed 2 in. from the bottom, but for soil of very low or non-uniform bearing resistance more than this amount may be required ; in such cases an engineer should be consulted. If the footing continues without a break under door openings, longitudinal bars are also required near the top. It is not advisable to leave a gap in the footing under openings, except on very firm ground, as otherwise the tying-in effect of a continuous footing is lost.

Walls.

The thickness of the walls depends on several considerations (apart from compliance with by-laws), such as the nature of the materials available for the concrete, whether the building is in a very exposed situation, and the nature of the surface finish, if any, to be applied to the wall. The wall must be weathertight. If the concrete is badly proportioned and mixed, and is of a porous nature, a wall will not be weathertight however thick it is made. It is necessary to employ good materials proportioned and mixed to give a dense concrete, and this must be thoroughly tamped. The thickness is generally from 4 in. to 6 in. and, provided the work is properly executed, walls of these thicknesses should be weather-resisting without the addition of any surface coat. The London Building By-laws require a minimum thickness of 4 in. for a reinforced concrete external wall, and 8 in. for a party wall ; if the wall is not reinforced the minimum thickness is $8\frac{1}{2}$ in. in each case.

Piers at the corners and other suitable positions in a wall sometimes improve the appearance and may result in a more economical structure. When piers are provided the cast-in-situ panels between them need be only 3 in. or 4 in. thick if lightly reinforced. Piers, however, introduce a complication in the shuttering, the cost of which may not be offset by the saving in concrete. Cast-in-situ walls of 3 in. or less in thickness are not generally satisfactory because of the difficulty and extra cost of placing and consolidating the concrete.

Projections required for decorative purposes or for the support of a gutter, for providing a bearing for the sole-plate of a roof truss, for the support of a wooden eaves-plate, or for similar purposes, must be cast at the same time as the wall. Some of the vertical reinforcement should be bent into the projection.

Chimneys and fireplaces can also be cast in situ. When the shape is so complicated as to make the shuttering costly, chimneys and fireplaces may be built of concrete bricks or blocks, bonded to the cast-in-situ walls by leaving bars

projecting from the walls and building the bars into the joints between the courses of bricks or blocks. A method of forming chimneys in situ is given later. If concrete bricks are used the chimneys are built in the same way as with clay bricks.

Reinforcement in Walls.

As before stated, reinforcement must be inserted to prevent or to control cracks, especially on large areas of wall. The reinforcement may consist of a light steel mesh or mild steel round bars equally spaced horizontally and vertically and wired together at every crossing. Where bars overlap the minimum length of the lap should be 1 ft. 3 in. in the case of $\frac{1}{4}$-in. bars, 1 ft. 9 in. for $\frac{3}{8}$-in. bars, and 2 ft. 6 in. for $\frac{1}{2}$-in. bars. The bars can be straight, but where they finish at an opening they should be hooked at the end or returned across the face of the jamb. The vertical bars should be embedded in the foundation concrete as before mentioned. *Fig.* 55 shows a typical arrangement for the reinforcement in a cast-in-situ wall.

The diameter and spacing of the bars should be such that the total volume of reinforcement is about 0·5 per cent. of the volume of the concrete. This amount is more than is often required for fire-resistance, but is considered necessary for other requirements. Suitable reinforcement, provided horizontally and vertically in the middle of the wall, is $\frac{3}{8}$-in. bars spaced at 12-in. centres in a 4-in. wall and at 9-in. centres in a 5-in. wall. For walls exceeding 5 in. in thickness the reinforcement should be placed in two layers, one near each face of the wall; suitable reinforcement in both directions in each layer is $\frac{3}{8}$-in. bars at 15-in. centres in a 6-in. wall, and at 12-in. centres in an 8-in. wall. The layer of reinforcement near the outer face of the wall should have a cover of concrete of 1 in. and that near the inner face a cover of $\frac{1}{2}$ in. Other amounts or arrangements of reinforcement can be provided to suit special conditions or to conform to the requirements of the authorities. Some regulations for fire-resistance require the spacing of the bars to be not greater than 6 in., in which case smaller bars can be used. The amount of horizontal reinforcement should be increased at external corners by inserting intermediate bars near the outside face of the wall.

In walls not less than 5 in. thick two $\frac{1}{2}$-in. bars should be placed horizontally over each opening and extend at least 18 in. beyond each side. Two $\frac{1}{2}$-in. bars should be placed vertically at each side of each opening and extend at least 12 in. beyond the top and bottom of the opening. In walls less than 5 in. thick a single $\frac{5}{8}$-in. bar should be placed over each opening and one $\frac{1}{2}$-in. bar vertically at each side of each opening. A $\frac{1}{2}$-in. bar should be placed diagonally across each corner of every opening and as near to the corner as possible; these corner bars are important in controlling cracks tending to spread outwards from the corner of the opening. In walls exceeding 6 in. thick, two diagonal bars should be placed across each corner of each opening. The foregoing bars, which are shown in *Fig.* 55, should be set in from the face of the concrete a distance of not less than $\frac{3}{4}$ in. or more than 1 in.

Piers should be reinforced by providing in each of the four corners a vertical bar of not less than $\frac{1}{2}$ in. diameter with not less than 1 in. cover of concrete. These bars should be tied together by means of horizontal binders formed of $\frac{1}{4}$-in. bars or wire spaced at 6-in. centres, as shown in *Fig.* 55.

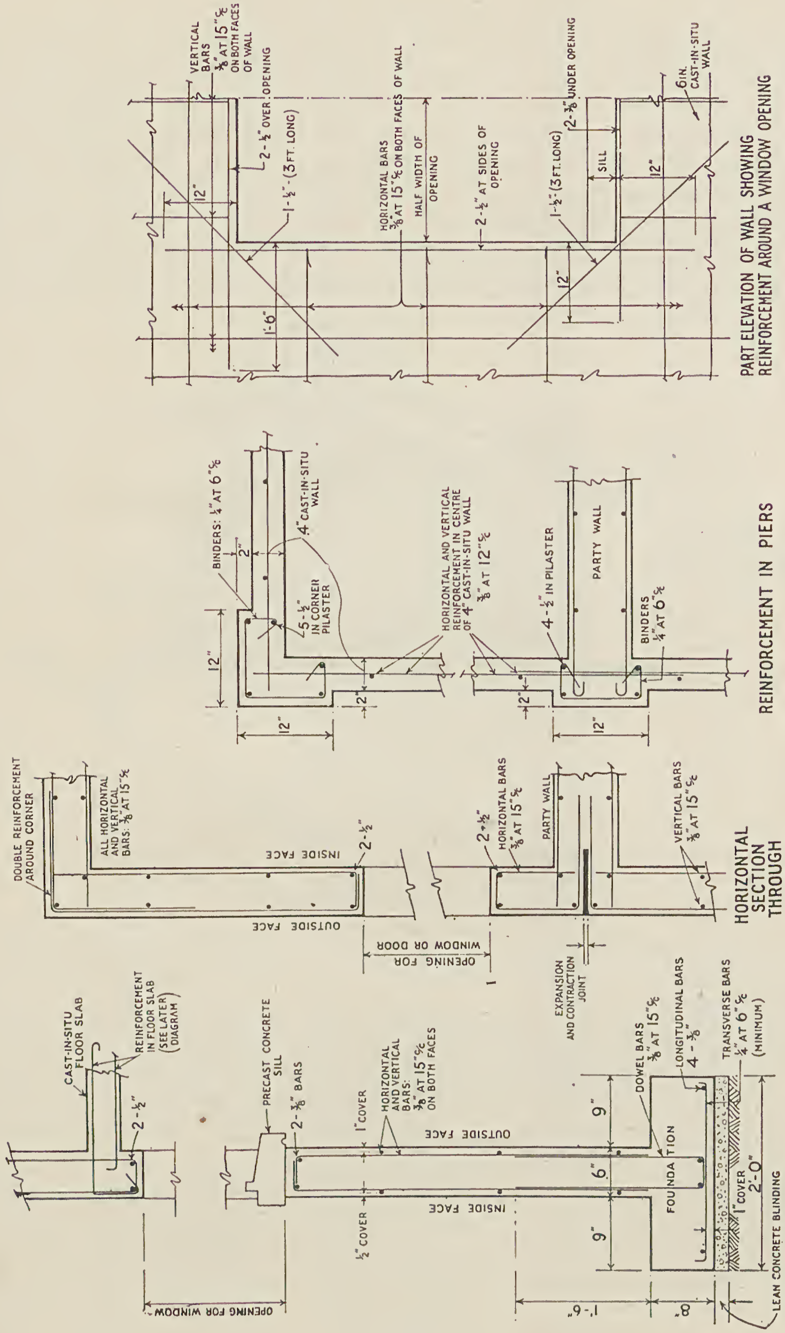


FIG. 55.—REINFORCEMENT FOR IN-SITU CONCRETE WALLS.

Timber Shuttering for Walls.

Timber shuttering may be erected for the whole of a wall or it may be built up in panels. *Fig.* 56 shows a method of erecting shuttering for the full height of a wall. It consists of 1-in. boards supported by 4-in. by 2-in. studs (or "soldiers") and braces spaced about 2 ft. apart and secured by pegs driven into the ground. As the shuttering increases in height further struts are necessary. With this type of shuttering it is possible, by increasing the size of the posts and struts to 6 in. by 3 in., to fix scaffolding directly to the shutters and so avoid separate scaffolding. The concrete should be placed in lifts of about 3 ft., and more boards and struts added as necessary so that further lifts of con-

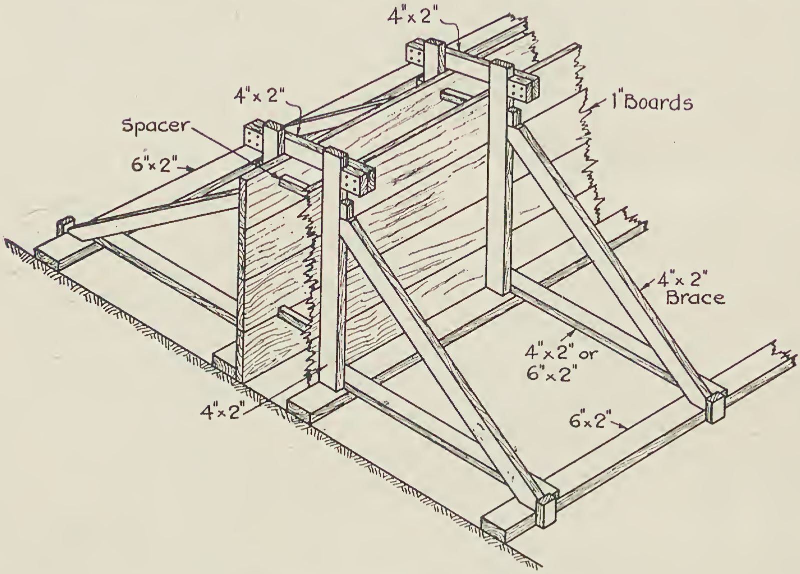


Fig. 56.—Wall Shuttering.

crete of about the same height may be placed. The shuttering should not be erected in courses of more than about 3 ft., or it will not be easy to place and tamp the concrete.

Fig. 57 is a design for panel shuttering. The size of each panel should not be too large, otherwise it may warp and will be too heavy for convenient handling. Where piers are provided the panels should be of a size to fit the spaces between the piers. The boards are 4 in. by 1 in. Double studs are shown so that bolts may pass between them and thus simplify erection.

In both types of shuttering the spacers, which hold the panels the required distance apart, are pieces of wood which are taken out as the concrete rises in the shuttering or concrete struts that may be left in. When the concrete is hard the bolts, which pass through the wall, are knocked through and the panels removed. An alternative is to use single 4-in. by 2-in. studs through which holes are drilled for wire ties which pass through pairs of studs and the ends of which are passed around a small bar and twisted to pull the panels against the spacers. The shuttering is stripped by cutting the ends of the wires and removing the

panels. The ends of the wires must then be cut back $\frac{1}{2}$ in. or so below the face of the concrete, chipping a hole in the face of the concrete to enable this to be done, otherwise rust stains will appear on the face of the wall. The holes must be filled with mortar which should match the colour of the wall if the wall is not to be rendered.

The method of using panel shuttering is first to erect a complete course around the house and fill it with concrete. When the concrete is sufficiently hard, the shuttering is removed and re-erected so that its bottom edge overlaps a few inches below the top of the bottom course of concrete. The second course is then concreted, and so on to the top of the wall. For the upper courses the shuttering may be supported on posts and struts, or it may be fixed from a scaffold. An alternative method is to provide sufficient shuttering for two courses ; the second

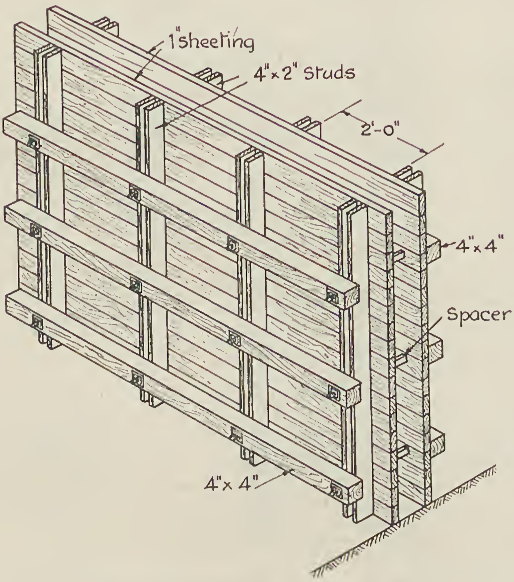


Fig. 57.—Panel Shuttering.

course of shuttering is placed on top of the bottom course after the bottom course has been filled, so that the panels for the course being filled are supported on the panels for the course below, which in turn are supported on the hardened concrete by means of bolts or wire ties.

Before use the inner faces of shuttering should be oiled to prevent concrete adhering to them, and each time it is stripped it should be thoroughly cleaned and re-oiled. Careful attention to oiling and cleaning, and a little time spent on repairs when necessary, will considerably prolong the life of shuttering. Tongued-and-grooved boards wrought on four faces should be used.

Where there is a considerable amount of repetition, steel shuttering is generally economical. Some examples of the use of steel shuttering are given later. Standard patterns of steel shuttering may be used, or special shuttering may be made to suit the houses to be erected.

CAVITY WALLS.—There are several ways of forming a cavity in an in-situ concrete wall, but the method mostly used is to insert a core of the desired width in the shuttering and raise it as the concreting proceeds. This method is only suitable when panel shuttering is used, as it is difficult to raise the core if it is more than 2 ft. or so in depth. The core may be of wood, but sheet steel is generally used. The steel is bent to U-shape, slightly wider at the top than at the bottom, and is suspended from metal strips temporarily fixed to the top edge of the shuttering. The method is indicated in *Fig.* 58. The core should be a little deeper than the depth of the panel of shuttering and the top of the concrete must always be kept a little higher than the bottom of the core so

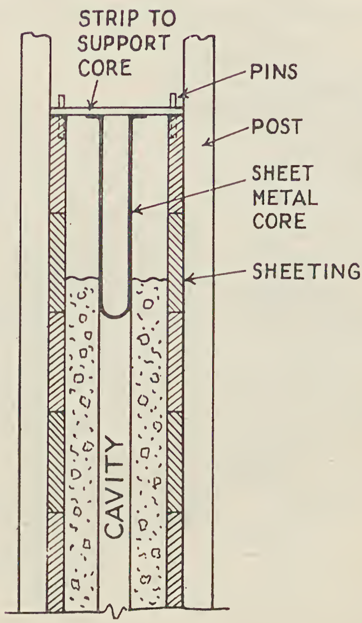


FIG. 58.—METHOD OF FORMING CAVITY IN IN-SITU CONCRETE WALL.

that the cavity is continuous. A simple method of keeping in position the metal strips resting on the top edge of the shuttering is to drill holes in the edge to coincide with holes in the metal strips, so that a peg can be passed through the hole in the metal strip and into the edge of the shuttering. When a cavity is formed in this way it is not possible to use wall ties.

A cavity can also be formed by movable plates held in position by vertical spacers of timber or steel, which should have the dimension across the cavity greater than that in the direction of the cavity. The short faces should be slightly rounded so that the spacers can be turned through 90 deg. after the concrete has set. When lightly tapped, the plates fall inwards and are easily removed. Wall ties should be placed at intervals of 1 ft. to 2 ft. horizontally across the cavity at the junctions of the courses of shuttering.

Openings for Doors and Windows.

The frames of doors and windows are often cast in as the work proceeds. This may save expense in shuttering and ensures secure fixing, especially if a few strips of hoop iron are attached to the frame, or long nails are driven into the frame and bent over and left projecting so that they become embedded in the concrete.

If windows, doors, or other frames are to be inserted after the construction of the walls, tapered plugs of hardwood (*Fig.* 59) should be built into the concrete (with the smaller end at the face) to take the screws by which the frames are fixed. It is important that the plugs should be accurately placed, especially

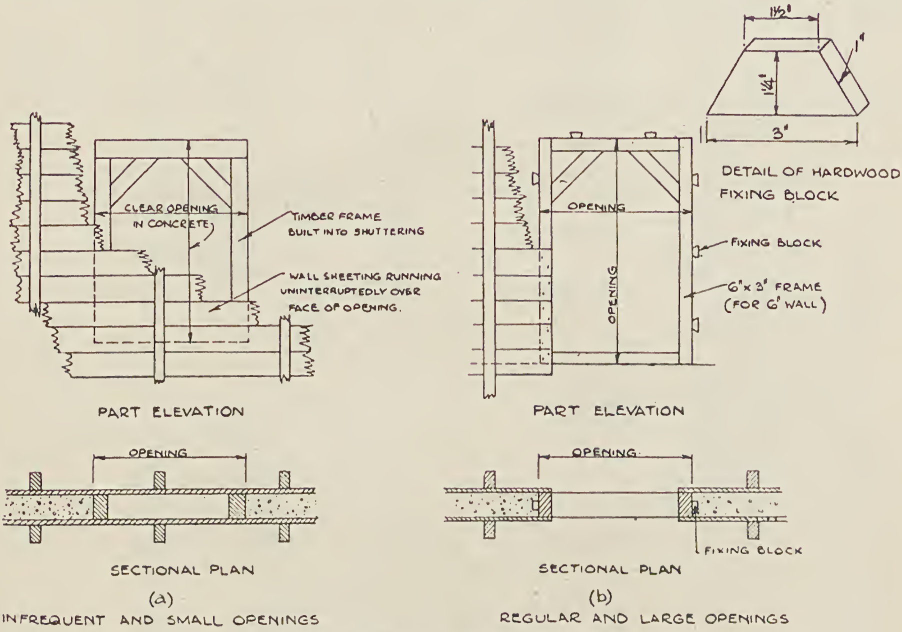


Fig. 59.—Forming Openings in Walls.

if metal frames, drilled for fixing screws before delivery to the site, are to be fixed. If a door frame or other frame is thinner than the thickness of the wall, it is better to form an opening in the wall and insert the frame later, as the provision of strips of shuttering to make up the difference is often costly.

Openings in walls for windows, doors, or other purposes, are easily formed if there are no cast-in-situ sills, heads, or other projections around the opening. If the openings are small in comparison with the area of the wall, or are irregular in position or few in number, the wall can be sheeted all over on both faces and a temporary frame the same width as the thickness of the wall inserted between the sheeting. Where the openings are regular or are large in area, the sheeting can be provided to cover the area of the wall only. The temporary frames are taken down after the shuttering has been removed. *Fig.* 59 shows these two arrangements for forming openings in walls, and indicates the stiffening required at the corners of the temporary frames and the plugs for fixing window and door

frames. The temporary frames should be lightly nailed to the plugs so that when the frame is removed the plugs remain in the concrete without straining the concrete in which they are embedded. In using fixing blocks care should be taken that the cover of concrete over adjacent reinforcement bars is not reduced below that required.

Instead of plugs, for fixing heavy door frames bolts are sometimes built into the concrete while it is being placed. Holes drilled through the temporary frame keep the bolts in position until the concrete hardens. If the bolts are left projecting the threads should be well greased before the concrete is placed so as to prevent spilled mortar adhering to the metal, as this is difficult to remove. Metal tongues attached to the frames are used to fix some types of pressed-steel door frames which are erected at the same time as the shuttering.

Openings in which metal window or door frames are to be fixed later should be of such a size that a clearance is provided beyond the overall size of the frame. With steel window and door frames a clearance of $\frac{1}{8}$ in. at the top, bottom, and

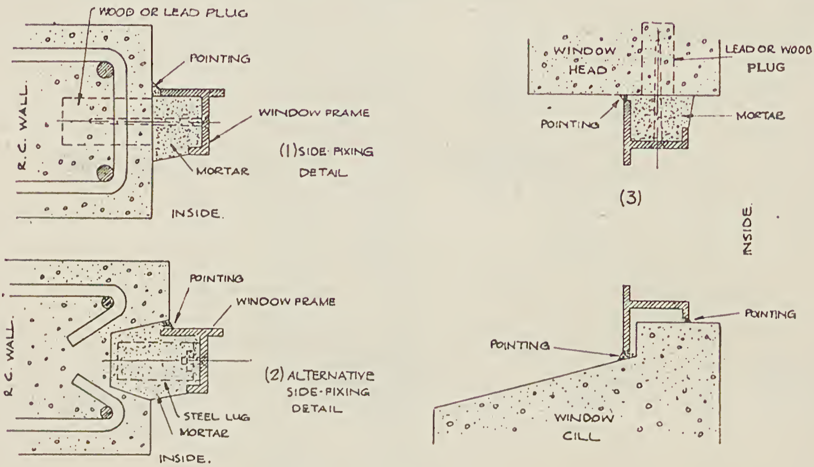


FIG. 60.—FIXING STEEL WINDOW FRAMES.

sides is advisable in excess of the nominal size of the frame, with an additional $\frac{1}{4}$ in. for each transom or mullion. The common methods of fixing steel window frames in concrete walls are shown in *Fig.* 60. In the method shown at (1) a wooden plug or a steel lug is inserted in the concrete opposite the screw-holes in the frames. The space between the frame and the face of the concrete is packed with mortar, and the gap between the outside edge of the frame and the concrete pointed with cement mortar or mastic. If this method is adopted the opening in the concrete must be truly rectangular.

The method shown at (2) allows some tolerance in the size of the opening and is suitable when the exact size of the window frame is not known when the wall is concreted. A rebate is cast in the sides of the opening by attaching a strip of wood of the required shape to the temporary timber frame. The window frame is secured by steel lugs attached to the frame and embedded in the mortar filling the rebate. Metal window frames are generally attached at the heads and sills, as well as at the sides, one method being shown at (3).

Partitions.

For internal partitions in houses it is not always economical to erect shuttering and cast them in situ, and there is no need to execute the work in this manner because there is no reason for making them weatherproof; breeze concrete partition slabs are satisfactory, or metal lath and plaster attached to a framework of timber may be used, depending upon the weight to be carried.

Support for Floors.

If the floor is supported on one or two precast concrete beams and the wall is less than 6 in. thick, a hole should be formed right through the wall at the position of each beam by inserting a block of wood between the inner and outer shuttering [*Fig.* 61 (*a*)]. The block should be split and provided with a tapered piece to facilitate removal from the set concrete. Alternatively, a cage of light

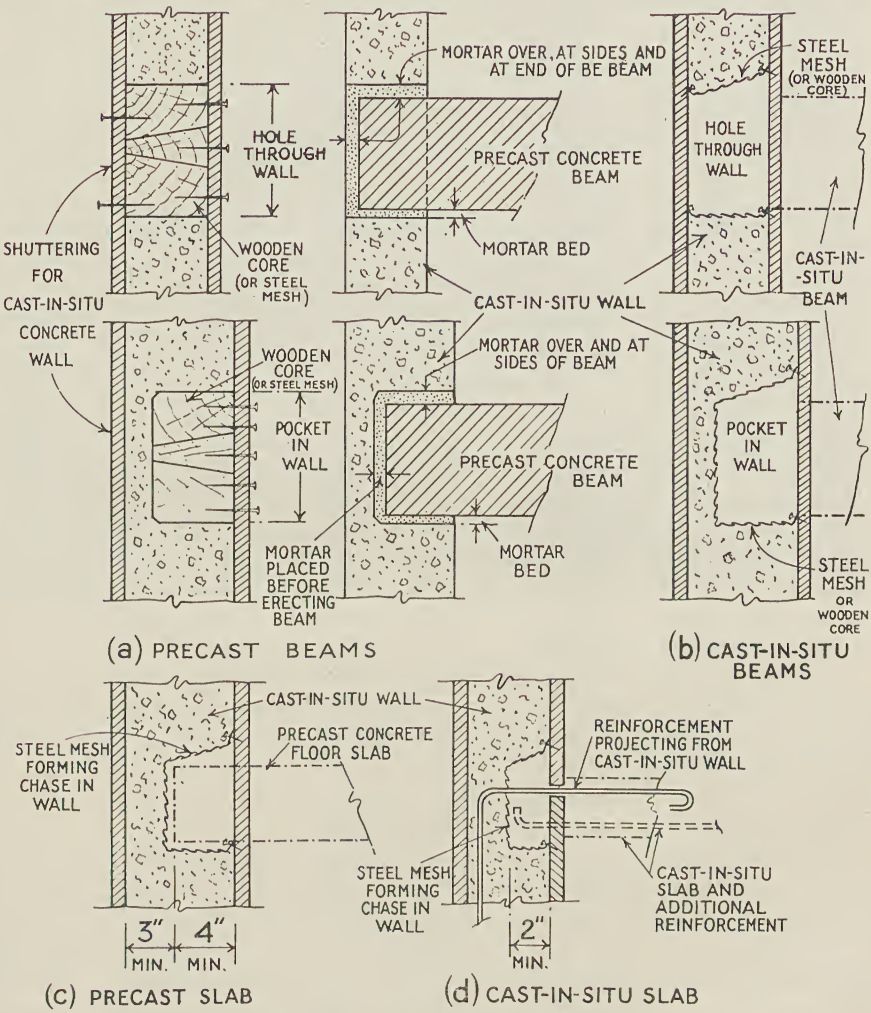


Fig. 61.—Methods of Supporting Floors.

steel mesh may be provided to form the hole. The steel mesh should be attached to the shuttering to secure it in place while concreting, but should not be too firmly fixed, otherwise removal of the shuttering, leaving the cage in position, is difficult. This method is probably not only cheaper than using a wooden block, but the steel mesh has not to be removed and forms an excellent key for the mortar or concrete filling the hole.

Each hole should be a little wider and deeper than the end of the beam, and the bottom of the hole should be about $\frac{1}{2}$ in. below the soffit of the beam. The end of the beam is set on a bed of mortar of a thickness to support the beam at the required level. The space above, at the sides, and beyond the end of the beam should be packed with mortar or fine concrete. If the wall exceeds 6 in. thick and a bearing not more than 5 in. long is required for the beam, the hole need not be made right through the wall, in which case the block or the steel mesh should be lightly nailed to the inner shuttering only.

If the beams are cast-in-situ the hole is filled with concrete when the beam is cast, but in this case the top edge of the hole should be sloped, as in [*Fig.* 61 (*b*)], to facilitate the tamping of the concrete in the cavity. As before, the hole can be formed either by a removable wooden block or by a permanent cage of steel mesh.

If the floor consists of closely-placed precast concrete floor beams or slabs requiring a continuous support on a cast-in-situ wall, a chase must be left in the wall. The bearing for the beams must be at least 4 in. wide, and since the chase must not extend right through the wall (otherwise the wall would be severed), nor must it temporarily weaken the wall, a thickness of at least 3 in. of cast-in-situ concrete should be provided between the chase and the outer face of the wall [*Fig.* 61 (*c*)]. This method is not recommended if the wall is less than 8 in. thick. The chase can be formed by a continuous strip of timber or preferably by steel mesh. If the walls are less than 8 in. thick it is better to cast them up to first-floor level, lay the floor beams, and then continue with the construction of the wall for the upper story.

If the floor consists of a cast-in-situ reinforced concrete slab it is sufficient to leave a chase about 2 in. wide [*Fig.* 61 (*d*)] with reinforcement bars projecting as shown to resist the tension in the top of the in-situ slab resulting from fixity with the wall. Owing to the complication produced by these bars, it is best to form the chase with steel mesh.

If the floor consists of wooden joists, a common method is to leave holes in the wall for bolts (or to build the bolts in at the time of concreting the wall), which will support a continuous timber plate affording a support for the joists which are attached thereto.

Steel Shuttering.

There are several types of steel shuttering, which differ mainly in the method of fixing. The shuttering generally comprises plates about 2 ft. high and up to 4 ft. wide, with smaller plates to make up heights and lengths of wall that are not multiples of 2 ft. or 4 ft. Each shutter consists of a thin metal plate with flanges around or near the edges and with intermediate stiffeners. Adjoining plates are secured to each other by bolts or clamps or wedges, and horizontal alignment is generally obtained by the use of steel angles.

The steel shuttering used for the houses illustrated in *Fig.* 69 is shown in *Fig.* 62 where the steel plates are wired to those on the opposite face of the wall. Other illustrations of the steel shuttering for these houses are given in *Figs.* 70 and 73.

The common procedure when using steel wall shuttering is to commence by erecting two tiers of shuttering on the footing. Generally enough shuttering is provided for two courses around the whole of the inside and outside of the walls. Concrete is placed first in the lower course and a few hours later, or on the

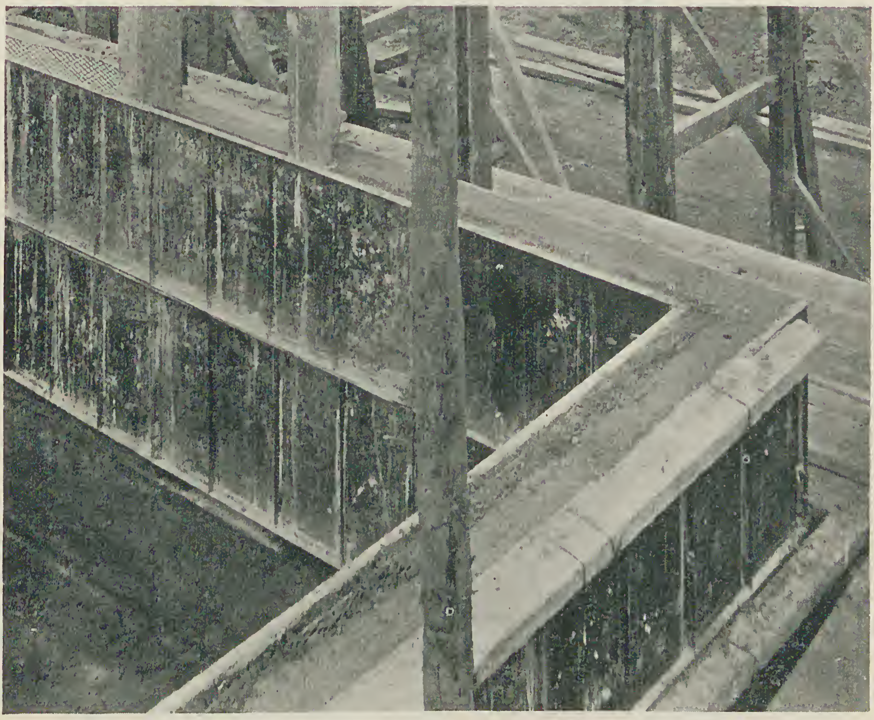


FIG. 62.—STEEL SHUTTERING USED IN THE CONSTRUCTION OF EXTERNAL WALLS OF TWO MATERIALS.

following morning, the top course is filled with concrete. Towards the end of the second day the bottom course of shuttering is removed, cleaned, oiled, and re-erected on top of what was the top course, and is ready for filling with concrete on the morning of the third day. What is now the bottom course is later in the day removed and re-erected on top of the course already filled, and so on until the top of the wall is reached.

The method of raising a course of shuttering each day so that the walls of a house can be completed within a fortnight (if only two courses of shuttering are used) is only possible with rapid-hardening Portland cement. If ordinary Portland cement is used the course in contact with the newly-placed concrete should be left for about two days before removal. Progress at the rate of one course each day can, however, be attained if sufficient shuttering for three courses is

provided. The use of three courses of shuttering in connection with the construction of walls of no-fines concrete is illustrated in *Fig.* 63.

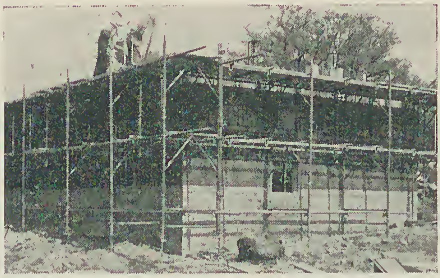


FIG. 63.—STEEL SHUTTERING FOR WALLS OF NO-FINES CONCRETE.

In the method shown in *Fig.* 64, the shuttering is erected to the height of the first story, which is concreted, and then for the upper story. The shuttering comprises H-shaped steel sections spaced 2 ft. apart, to which light pressed-steel shutter-plates 2 ft. 8 in. by 2 ft. are fixed by small quick-acting slotted pins and wedge cotters. The plates have flanges at the sides, and are stiffened by transverse ribs. Door frames are inserted as the shuttering is erected, and steel moulds are used to form moulded concrete surrounds to these and to window

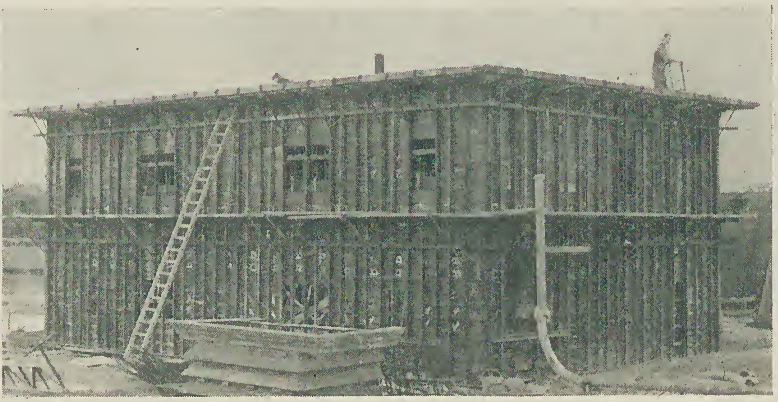


FIG. 64.—STEEL SHUTTERING FOR LOWER AND UPPER STORIES.

openings. The same type of shuttering is used to form the partition walls, which are concreted at the same time as the outer walls. The use of a pump to convey the concrete from the mixer to the shuttering is shown in *Figs.* 67 and 68. When ordinary concrete is used to fill shuttering the full height of a story special care must be taken to tamp the concrete at the bottom of the shutters; also, because it is not easy properly to consolidate concrete dropped to the bottom of shuttering 8 ft. or 9 ft. high, it is necessary to use a wet mix which may lose grout through the joints in the shuttering if the plates do not fit closely.

As with timber shuttering, walls cast within steel shuttering are generally

constructed to eaves level in a continuous series of operations, provision being made for the support of the first floor which is constructed after the completion of the walls. There is with steel shuttering greater difficulty in securing wooden blocks or steel mesh for forming pockets or chases for this purpose unless the horizontal joint between the plates at first-floor level is at the proper height.

Construction of Cast-In-Situ Walls.

Size of Mixer.—The speed at which the concrete can be deposited and consolidated in the shuttering generally decides the rate of progress of the work. It is not necessary to have a concrete mixer or distributing equipment of much greater capacity than the amount of concrete that can be dealt with by the men placing and tamping the concrete into position. The output of a mixer with a capacity of 5 cu. ft. or 7 cu. ft. of mixed concrete is all that one gang of men can deal with in this class of work.

Transporting Concrete.—When placing the concrete in the bottom 3 ft. of the wall, the concrete can be brought from the mixer in steel wheelbarrows from which it is shovelled between the shuttering, and men standing at ground level can conveniently use tamping rods to consolidate the concrete. As the

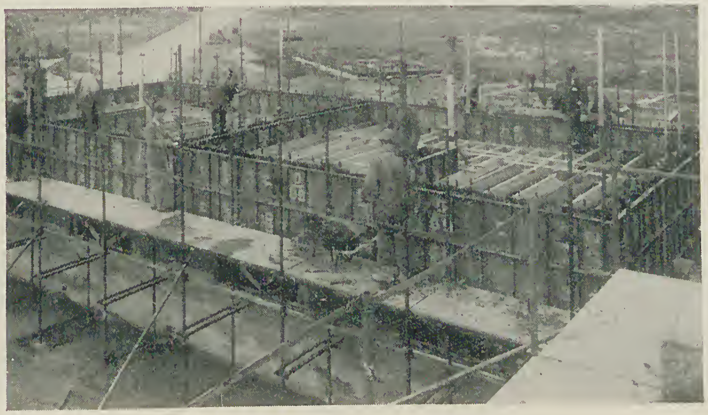


Fig. 65.

working level is raised the concrete has also to be raised, and a method which is satisfactory up to the level of the first floor is to provide an inclined ramp of scaffold boards supported on steel scaffolding. The barrows are wheeled up the ramp to a scaffold at the level of the shuttering, and are emptied directly into the shuttering. Other methods are to raise the concrete in skips hoisted by a gin wheel, or to use a barrow-hoist. If a hoist is used it should be in a central position outside one of the external walls. As an external scaffold is required for the men removing and re-erecting the outside panels of shuttering, and for finishing operations, this scaffold can be used by the men placing the concrete. The method of distributing concrete shown in *Fig.* 65, and the scaffolding shown in the same illustration and in *Fig.* 66, is suitable whether steel or wooden shuttering is used.

If all the main operations are carried out from an external scaffold, an internal scaffold is generally required at the party wall and a partial internal scaffold

Fig. 66.

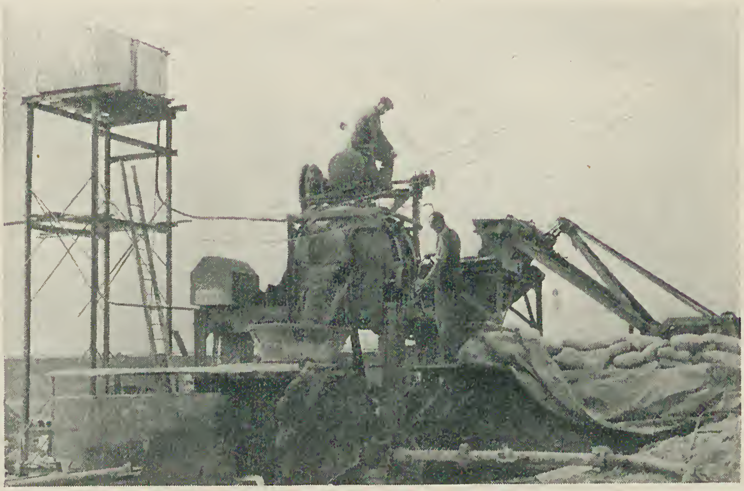


Fig. 67.—Concrete Mixer and Pump: Pipeline in Foreground.

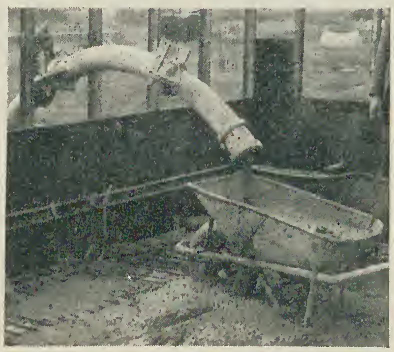


Fig. 68.—Pipeline from Concrete Pump Discharging into a Barrow.

for men working on the inside shuttering. The plastering will generally be done after the floors are built, in which case the plasterers can work on trestles standing on the floor.

The use of a pump for transporting concrete is shown in *Figs.* 67 and 68. The aggregates are taken from the stockpile and loaded into a bin by a mobile shovel, and are discharged from the bin into a weigh-batcher and thence to the skip of a mixer. The concrete is fed from the mixer into a pump having a capacity of 10 cu. yd. per hour. When the shuttering and reinforcement for the lower story are in position the concrete for the full story height is placed, including the reinforced concrete suspended first-floor slab, the pipeline from the pump delivering the concrete at first-floor level. The remainder of the shuttering and reinforcement for the walls and the flat roof are then fixed, the pipeline extended to roof level, and the concrete for the walls of the upper story placed in the same way with the use of barrows (*Fig.* 68). The concrete for the flat roof and projecting eaves is then placed and screeded to fall to the gutters.

Placing the Concrete.—Tamping should be carried out in such a way that the new concrete is well rammed against the surface of the concrete below, and continued until bubbles of air cease to appear on the surface, when tamping should be stopped. Excessive tamping is injurious as it brings water and fine material to the top. The concrete must be well spaded against the face of the shuttering to produce a hard and dense surface, but not a surface that is deficient in aggregate and that has an excess of cement mortar. Properly-controlled mechanical vibration is helpful in accelerating the work of consolidating the concrete if fairly dry mixtures are used, but excessive vibration can be injurious as it results in separation of the materials in the concrete.

The concrete should be placed in the shuttering in layers not exceeding 1 ft. deep and each layer must be well consolidated before depositing the next layer. It is desirable that the concrete be deposited to a uniform height around the house or block of houses in one working day so as to avoid vertical construction joints.

In some systems of construction the shuttering for the walls is erected for the full height of one or both stories and the concrete is deposited from the top and the walls for one story, or in some cases for two stories, are cast in one working day. It is necessary with this method to use a more workable concrete than is the case when a height of only 3 ft. or so is cast at one time, and care must be taken to ensure that the concrete near the bottom of the walls is not honeycombed and that near the top deficient in aggregate.

Walls with Impervious Outer Face and Porous Inner Face.

The external walls may have an impervious concrete exterior and a porous concrete interior. For example, if the external walls are 8 in. thick, the outer 5 in. may consist of ballast concrete and the inner 3 in. of clinker concrete, both concretes being mixed in the proportions of 1 part of Portland cement to 7 parts of aggregate. The two concretes placed at the same time are separated by wire netting, which is fixed in the shuttering before the concrete is placed and left in the wall. Over all openings the walls are strengthened by increasing the richness of the concrete to 1 : 5, and this concrete is also used in the eaves course.

Some houses built by this method at Welwyn Garden City are illustrated in *Fig.* 69. Steel shuttering was used for the construction of the walls as already described; in *Fig.* 62 the difference in the appearance of the two concretes is seen. The external walls are reinforced with $\frac{1}{2}$-in. bars placed horizontally at 18-in. centres in the ballast concrete.

Elsewhere clinker concrete has been used for the inner leaf of external walls 8 in. thick, including a 2-in. cavity. The outer leaf is 3 in. thick and is com-

FIG. 69.—CONCRETE HOUSES AT WELWYN GARDEN CITY.

posed of shingle concrete in the proportions of 1 : 7. The inner leaf is of clinker concrete 3 in. thick and the two leaves are tied together with galvanized wall ties. In some houses at Gosport the 3-in. internal partition walls are of clinker concrete, and the party walls are 8 in. thick and also of clinker concrete. The outer leaf is reinforced with $\frac{1}{2}$-in. bars above and below openings. When porous aggregate such as clinker is used for the full thickness of a wall the outer face must be rendered to make it weatherproof.

No-fines Concrete.

No-fines concrete is a mixture of Portland cement and gravel or clinker from which most of the pieces smaller than $\frac{3}{8}$ in. have been removed. Generally, pieces below $\frac{3}{8}$ in. are allowed, and in fact are advantageous, if they are not present in excess of 5 per cent. The proportions may be 1 part of Portland cement to 6 parts of aggregate. In Scotland no-fines concrete has been used for houses when mixed in the proportions of 1 part of Portland cement to 8 parts of screened broken whinstone. The quantity of mixing water is not sufficient to form a cement paste that will flow, and therefore close-boarded shuttering is not necessary. The cement paste is, however, sufficiently liquid to surround completely each piece of aggregate thereby ensuring, when hardened, a concrete containing a large proportion of voids.

The principle advantages of no-fines concrete for the walls of houses include the high degree of thermal insulation provided, the cheapness of the concrete and the shuttering, and the low weight. The principle of no-fines concrete was developed in Holland in the early 1920's, and was used probably before this in isolated cases.

External walls are generally 8 in. thick, although in some houses they are 12 in. thick. Reinforcement is provided around openings in the walls. Internal load-bearing walls 4 in. thick, and lintels, or continuous courses at the levels of the window heads and eaves, are constructed in ordinary dense gravel concrete. Chimney breasts are built either in brick or in ordinary dense gravel concrete. Owing to the open texture of the surface of no-fines concrete it is necessary to render the outside face and to plaster the inside face ; the rough surface provides an excellent key for the rendering and plaster. In some houses the stringcourses of ordinary concrete do not extend the full width of the wall, but allow a facing of no-fines concrete about 2 in. thick, thus preserving a uniform external surface concrete to take the rendering.

Although close-boarded shuttering or steel shuttering has been used for walls of no-fines concrete, the shuttering generally used consists of steel mesh fastened to wooden or steel frames. The mesh has diamond-shape openings measuring about $\frac{1}{2}$ in. by $\frac{1}{4}$ in.

Curing.

The treatment of the concrete after the removal of the shuttering is of great importance if a durable concrete wall is to be obtained. As described in the foregoing, the shuttering is generally removed from the walls a day or two after placing the concrete, at which age the concrete has not enough strength to resist shrinking and other tensile stresses, although it has sufficient strength to resist the compressive stresses imposed upon it by the weight of the upper portions of the wall. Early drying of the concrete must therefore be avoided, and this can be done by watering daily or as often as is necessary to keep the surface damp. In very hot weather or in positions exposed to drying winds, wet cloths should be hung against the face of the wall or, immediately after watering the face, protection against drying should be provided by hanging tarpaulins or building paper close to the wall. The surface should be kept damp for at least seven days after placing the concrete if ordinary Portland cement is used or for three to four days if rapid-hardening Portland cement is used.

In wet weather artificial moistening of the surface is unnecessary and in shaded parts, such as below an internal scaffold, less watering may be required to keep the concrete moist. In frosty weather, or when a frost is predicted, water should not be applied to the concrete as the effect of water freezing in the pores is disruptive.

Chimneys and Fireplaces.

In cast-in-situ construction chimney breasts, fireplace openings, and flues are often constructed together with the walls.

Fig. 70 shows a method of constructing the chimney flues and fireplace openings for the houses illustrated in *Fig.* 69. Steel shuttering is used, and on the left of the illustration are seen the wooden cores for blocking-out the fireplace

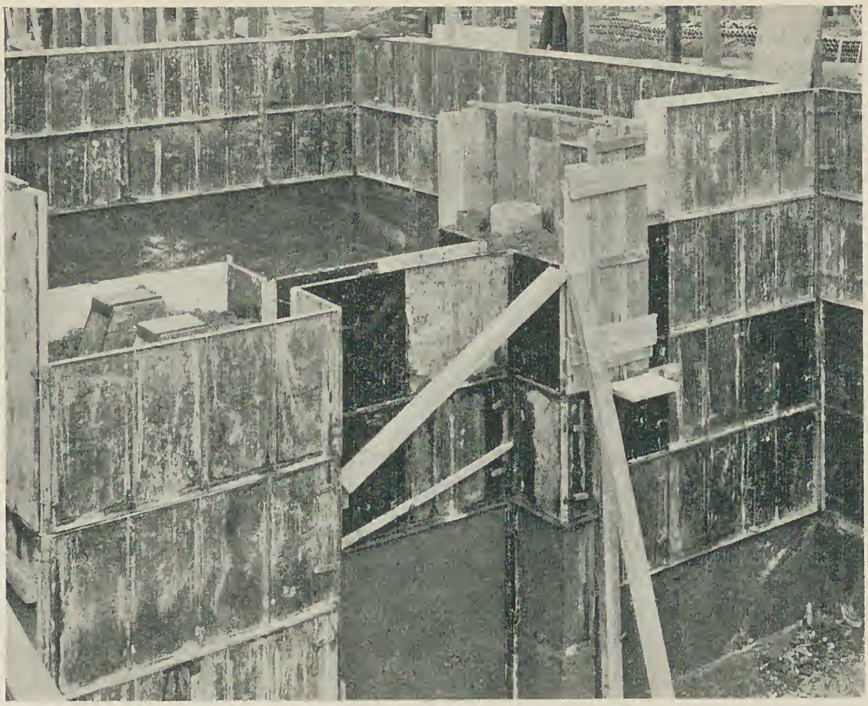


Fig. 70.—Concrete Chimneys in Course of Construction.

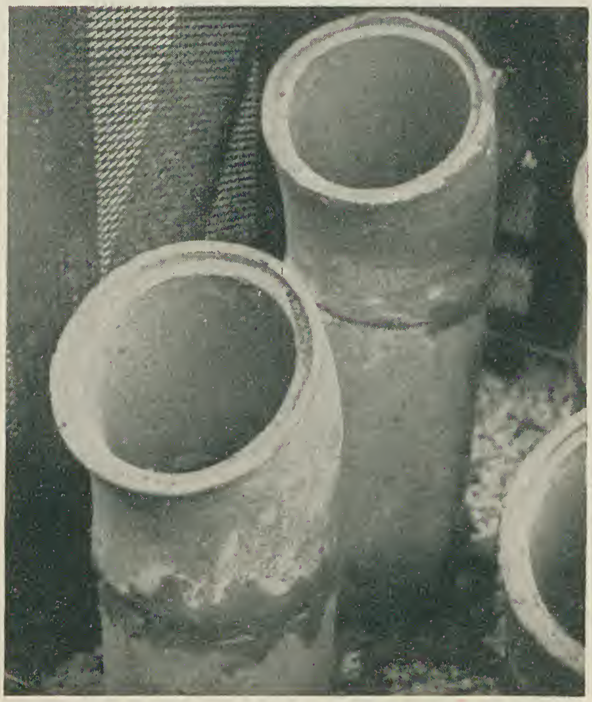


Fig. 71.—Fireclay Flues in Concrete Chimney.

openings; on the right is shown a method of constructing the flues by building in 9-in. fireclay tubes. Additional lengths of fireclay tube are set and secured in position as the construction proceeds. Curved tubes are used where necessary and, where there is any possibility of the concrete falling into the tubes, a wooden core slightly smaller in diameter than the tube is inserted when the work commences and is drawn up as construction proceeds, bringing with it any loose concrete that may have fallen into the tube. *Fig.* 71 shows curved fireclay flues in position. In this case 8-in. diameter fireclay flue-linings are provided for open coal fires, and 6-in. asbestos-cement pipes are used for conducting warm

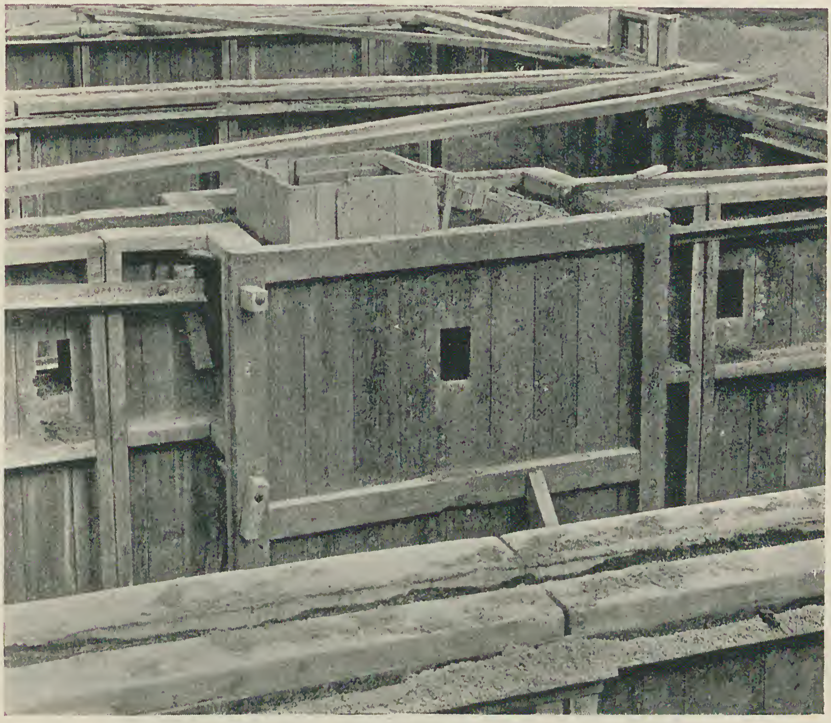


FIG. 72.—FORMING FLUES BY WOODEN CORES.

air from the living-room stoves to the bedrooms. The chimney breasts are built with foamed-slag aggregate.

Glazed earthenware pipes are sometimes built into walls to provide flue-linings. Flue-linings for open fires can be made in precast concrete using refractory aggregates such as pumice, foamed-slag, blastfurnace slag, or broken brick.

Standard precast concrete flue-linings have an internal diameter of 8 in., and consist of straight tubes $11\frac{5}{8}$ in. long and curved tubes subtending an angle of $37\frac{1}{2}$ deg., the radius of the centre-line being 1 ft. $9\frac{1}{4}$ in. The joints between the pipes are butt, ogee, or rebated. Precast concrete flue-linings for gas fires are of various shapes and provide a single or double rectangular opening. They are made with a refractory aggregate or with gravel aggregate.

A method of forming square flues by inserting wooden cores within the concrete chimney breasts, shown in *Fig.* 72, was used in some cast-in-situ concrete

houses erected for the Gloucester City Council with timber shuttering. The cores have tapered draw-pieces so that they can be easily released and removed for re-use.

Expansion and Contraction Joints.

In a single house or a pair of houses of one or two stories, provision for expansion and contraction of cast-in-situ walls due to changes of temperature is not generally required. If means are taken, as already described, to cure properly the hardened concrete, and reinforcement is provided as described, no further provision is generally necessary to counteract cracks due to the shrinking of the concrete. In the case of extreme exposure of a pair of houses and in a terrace of houses, some means of relieving the stresses resulting from movements due to changes of temperature and to shrinking may be required. Only the external walls may be seriously affected by such movements if restrained, but relief can

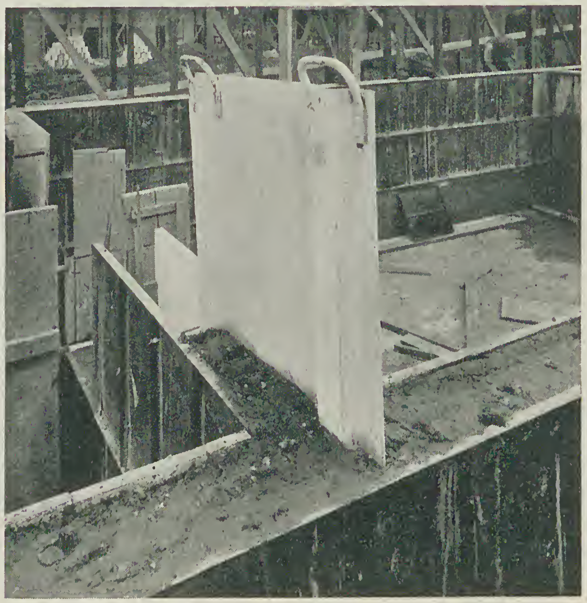


Fig. 73.

be afforded by the provision of a vertical joint, for example at the party walls. An expansion and contraction joint at a party wall is illustrated in *Fig.* 73. The joints are $\frac{1}{4}$ in. wide, and extend 2 ft. from the face of the external wall along the centre of the 6-in. party wall. A steel plate $\frac{1}{4}$ in. thick is inserted within the shuttering at ground level and drawn upwards by the handles at the top as the work proceeds. This leaves a gap $\frac{1}{4}$ in. wide, through the 8-in. external wall and 16 in. into the party wall, which is not filled, showing on the face of the external wall. To prevent rain driving through the gap the joint has two bends within the thickness of the outer wall, so that moisture does not get as far as the porous clinker concrete used on the inner face of the wall and in the party wall.

CHAPTER V

CONSTRUCTIONAL DETAILS

Floors.

GROUND floors and upper floors may be constructed of timber or concrete, and the finish may be boards, tiles, cement mortar, granolithic, or linoleum.

GROUND FLOORS.—The ground floor may be formed either directly on the site concrete or it may be raised on sleeper walls and constructed with wooden joists and boards. The former method is cheaper because in any case a layer of concrete must be laid on the ground and it is economical to employ this as the base of the floor. The site concrete should be 4 in. or 6 in. thick, 4 in. being generally sufficient, and there is no need for reinforcement. A 1 : 2½ : 5 concrete is strong enough provided that the materials are clean, well-graded, and properly mixed. Any of the surface finishes mentioned may be adopted, boards being suitable for living- and sitting-rooms, tiles for kitchens and sculleries, and cement mortar for larders. Granolithic will generally be satisfactory for floors where hard-wearing qualities are required and where the coldness of the surface is not objectionable.

The cheapest finish is obtained by screeding and floating the concrete immediately it is laid, scattering a small quantity of neat cement over the surface to take up the surplus moisture and enable the surface to be floated. This should be done by rubbing a wooden hand-float lightly over the concrete to ensure a uniform finish. Just before final setting takes place (say, three or four hours after the concrete is placed) the surface should be smoothed with a steel hand-float, using heavy pressure to produce a dense finish ; this will withstand considerable wear without the surface flaking off because the floor is of the same material throughout and laid in one operation. A considerable saving will be made by this method compared with granolithic. A simple treatment for a smooth concrete floor where a concrete surface is not objectionable is to apply one or two coats of creosote, or a solution made by dissolving a handful of ferrous sulphate in a gallon of water, and afterwards polish with floor polish. If floors are coloured in this way care must be taken to apply the creosote or ferrous-sulphate solution evenly, or a patchy surface will result ; extra coats will deepen the shade, or in the case of the cheaper ferrous-sulphate treatment, a stronger solution will give a deeper shade of buff or brown.

When boards are used without sleeper walls care must be taken to prevent them being laid so that dry rot may occur, and this precaution is particularly necessary if the floors are covered with linoleum or other material which prevents the circulation of air over the upper surface or through the joints. The boards

are either nailed to wooden or breeze-concrete fillets cast in the surface of the site concrete or they are spiked directly to the latter when breeze is used as the aggregate. The fillets are splayed to ensure a hold in the concrete, and if they are of wood they should be creosoted or treated with other preservative before they are inserted in the concrete. The difficulty of the ventilation of the small space under the boards, as the fillets only project a short distance above the concrete, has led to the practice of spiking the boards directly to the concrete, and if this is properly done it gives satisfactory results. The following points should be given attention. The boards should be tarred on the underside and bedded solid on to the concrete. The concrete should be thoroughly dry before the boards are laid. When gravel concrete or similar concrete is used for the site concrete a layer of breeze concrete must be laid on the top to take the spikes and this should be made level.

It is essential that the concrete should be allowed to dry thoroughly before linoleum is laid, or the dampness will cause the covering to rot. The concrete must be impervious or a damp-proof course should be laid, or there will be a risk of damp coming through from the ground below.

Upper Floors.—Upper floors are frequently constructed with timber joists and boards, but reinforced concrete in the form of precast beams and slabs or cast-in-situ slabs, or a combination of both methods, is sometimes used whether the walls are in concrete or brick. Careful consideration is necessary in designing the floor if economy and stability are to be obtained. In the case of floors for houses the load to be carried is small. For houses of not more than two stories the superimposed load on the floor slabs can be assumed to be 30 lb. per square foot, but on a floor having a span of less than 8 ft. the slab should be designed for a minimum uniformly-distributed load of 240 lb. per foot width of slab. If it is necessary to insert beams to support the slab, they should be designed to carry a load of 30 lb. for each square foot of the area of the slab supported. If a beam supports an area of less than 64 sq. ft. the beam should be designed to carry not less than 1920 lb. These loads are in addition to the weight of the floor.

For the foregoing loads and with beams provided as shown in the plans of Type No. 2, *Figs.* 23 and 24, and assuming a boarded finish to the bedroom floors, a cast-in-situ slab 3-in. thick is required if 1 : 2 : 4 concrete of ordinary quality is used. The reinforcement required in the bottom of the slab at the middle of each span and over the tops of each beam is ¼-in. bars spaced at 4½-in. centres. A suitable size for the beams is 5 in. wide with 6 in. projection below the slab. The reinforcement in the beams should be two ¾-in. bars in the bottom, two ⅜-in. bars in the top, and ¼-in. binders at 9-in. centres. If there is an objection to the beams spanning across the ceiling of the living-room these can be omitted, and the slab then required would be 4 in. thick reinforced with ⅜-in. bars at 4½-in. centres, the bars being laid at right angles to the front of the house. At right-angles to these bars, ¼-in. bars at 12-in. centres should be laid and wired.

When boards are to be used for the surface a layer of breeze concrete can be laid as described for ground floors, and the boards nailed to the breeze concrete without the use of fillets. The breeze concrete should be additional to the slab of ordinary concrete. When cement mortar or granolithic is used as the floor surface a narrow wooden fillet to which a carpet can be nailed is sometimes provided all around the room near the walls and flush with the finished surface.

It is essential to provide a proper bearing for the floors on the main walls and partitions, and in the case of cast-in-situ reinforced concrete floors these should, if possible, be constructed when the work has been built up to the bearing

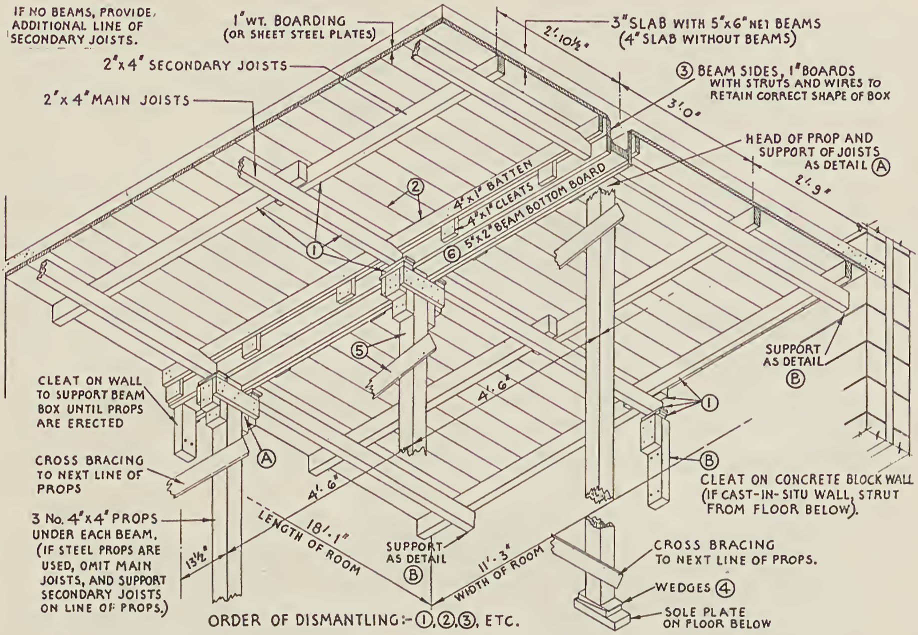


FIG. 74.—SHUTTERING FOR UPPER FLOOR OR FLAT ROOF.

level rather than by leaving chases in the work. When the outer walls are built with hollow blocks, for example, and the partitions carrying the floor are of solid blocks 4½ in. thick, the walls should be built up to the bearing level, the shuttering for the floor erected, and the floor constructed over the whole area so that it bears on the full width of the inner leaf of the external walls and is continuous over the partitions. When the floor has hardened, the walls and partitions for the second story are built on the reinforced concrete floor. This is often the most economical method, as hoisting and placing of the concrete are easier and the finished floor is available for working on when the upper part of the house is being built. When reinforced concrete walls are used, the cast-in-situ concrete floor can be constructed at the same time as the walls, or the method shown in *Fig.* 61 (*d*) can be adopted. It is important that the reinforcement be carried from the walls into the floor slab to form a monolithic structure. The shuttering for reinforced concrete floors for houses is simple, consisting of boards supported by joists carried on vertical posts and sole-pieces; wedges should be placed between the posts and the sole pieces so that the posts can be easily removed after knocking out the wedges. Occasionally shuttering for small beams will be necessary. No elaborate trimming or strutting is needed. A design for the shuttering for the upper floor or flat roof of the house shown in *Figs.* 23 and 24, with and without beams, is given in *Fig.* 74.

The provision of precast concrete beams and slabs avoids the use of shuttering and delay while the concrete hardens before proceeding with the upper story.

There are several designs of precast floors suitable for houses. In some of these the disadvantage of precast construction not being in general a monolithic or continuous construction is overcome by providing cast-in-situ connections between

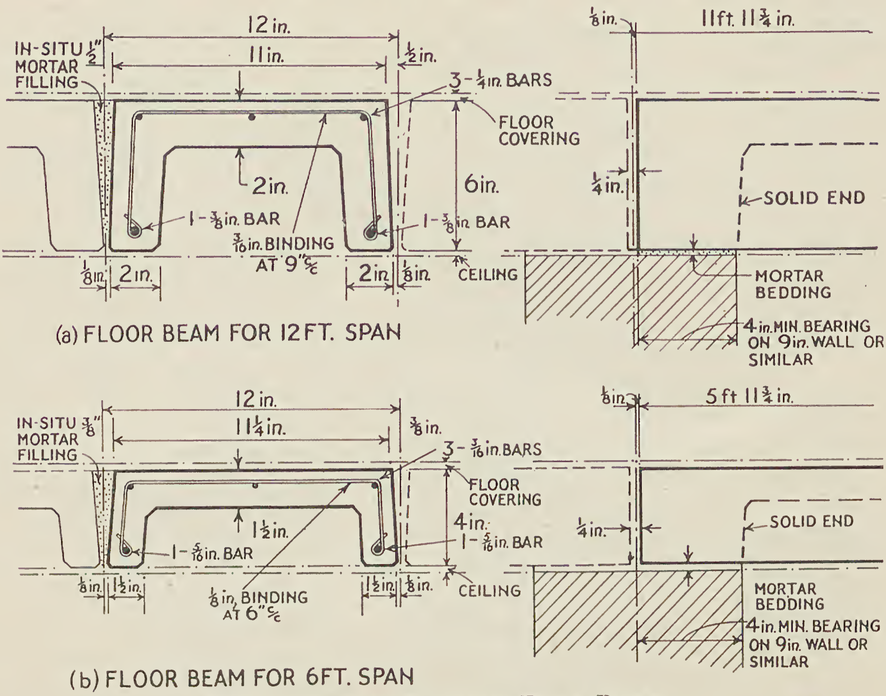


FIG. 75.—PRECAST CONCRETE FLOOR BEAMS.

the precast beams and slabs. In no case, however, is much shuttering required for the cast-in-situ concrete.

A design for a precast concrete floor beam is shown in *Fig.* 75, the object of the trough shape being to reduce its weight. If the length of the beam is 12 ft. the overall depth should not be less than 6 in., and the dimensions and reinforcement shown at (*a*) are satisfactory. The two bottom bars resist the tendency of the beam to bend when it is loaded, and the two top bars resist tensile forces incurred while handling and erecting the beams. The purpose of the binders is mainly to hold the longitudinal bars in position during concreting, but they also slightly strengthen the web and flanges of the beam. If the beam spans only 6 ft. the total depth can be reduced to 4 in. and the reinforcement in the bottom can be as shown at (*b*). In both cases the concrete should be mixed in the proportions of 1 : 1½ : 3 by volume, using coarse aggregate not larger than ½ in. No bar or binder should have less than ½ in. cover of concrete.

When ordinary wooden floors are used they are built in the usual manner and finished with lath and plaster or ceiling board on the underside. Concrete floors require only a skimming coat of plaster on the ceilings of the principal rooms, while in sculleries and suchlike apartments no treatment, except whitewashing or distempering, is necessary if care is taken to provide a reasonably good surface to the soffit of the slab. Another advantage of reinforced concrete floors compared with wooden floors is a small saving in the height of the building,

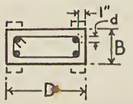
as the average thickness of the finished concrete floor is about 6 in. or less compared with 11 in. for a wooden floor.

Columns.

The following notes relate to the load that can be placed with safety on precast and cast-in-situ interior columns, and on precast columns in external walls and at the corners of external walls. The greatest load that a column can safely support depends on the strength of the concrete, the amount of reinforcement, whether or not the load is eccentric, the height and shape of the column, and the method of fixing the ends. The conditions on which the accompanying tables are based are the following. The concrete is assumed to be mixed in the proportions of 1 : 1½ : 3 and the strength of 6-in. cubes at 28 days to be not less than 3300 lb. per square inch. For concrete having any other strength the safe load is proportional to that strength. The reinforcement is mild steel bars and binders, and the volume of the main bars is not less than 0·8 per cent. of the volume of the concrete in an interior column, 1 per cent. in an external wall column, and 1½ per cent. in a corner column. It is assumed that there is at least 1 in. of concrete around each bar. The volume of the binders is not less than 0·4 per cent. of the volume of the concrete and the spacing of the binders does not exceed twelve times the diameter of the main bars, thereby conforming to ordinary practice.

The load on an internal column is generally assumed to act centrally on the

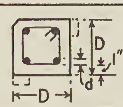
TABLE II.—SAFE LOADS (IN TONS) ON EXTERNAL COLUMNS.



SAFE LOAD (TONS)
1:1½:3 CONCRETE
(Crushing Strength = 3300 lb. per square inch at 28 days.)

B (IN)	D (IN)	REINFORCEMENT: MAIN BARS d (in.)	REINFORCEMENT: BINDERS	HEIGHT OF COLUMN (FEET): 8	9	10	12
4	6	⅜	3/16" at 3"	1¾	1	-	-
	8	⅜	3/16" at 3"	2¼	1¼	-	-
	10	⅜	3/16" at 3"	2¾	1½	-	-
5	6	⅜	3/16" at 3"	4	3	2	½
	8	⅜	3/16" at 3"	5	4	2¾	½
	10	½	¼" at 4½"	6½	5	3½	¾
6	8	½	¼" at 4½"	8	7	6	3½
	10	½	¼" at 4½"	10	8½	7	4¼
	12	½	¼" at 4½"	11½	10	8¼	5

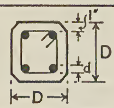
TABLE III.—SAFE LOADS (IN TONS) ON CORNER EXTERNAL COLUMNS.



SAFE LOAD (TONS)
1:1½:3 CONCRETE
(Crushing Strength = 3300 lb. per square inch at 28 days)

D (IN)	REINFORCEMENT: MAIN BARS d (in)	REINFORCEMENT: BINDERS	HEIGHT OF COLUMN (FEET): 8	9	10	12
6	½	¼" at 4½"	5	4¼	3½	2
8	⅝	5/16" at 7½"	11	10	9	7¼
10	¾	5/16" at 6"	18½	18	16½	14½
12	¾	⅜" at 7½"	25	25	25	22½

TABLE IV.—SAFE LOADS (IN TONS) ON SQUARE INTERNAL COLUMNS.



SAFE LOAD (TONS)
1:1½:3 CONCRETE
(Crushing Strength = 3300 lb. per square inch at 28 days)

D (IN.)	REINFORCEMENT: MAIN BARS d (in)	REINFORCEMENT: BINDERS	HEIGHT OF COLUMN (FEET): 8	9	10	12
6	⅜	3/16" at 3"	13	11¼	9½	5½
7	⅜	¼" at 4½"	20	19	16	11¾
8	½	¼" at 4½"	30	27½	25	20
9	½	5/16" at 6"	38¾	37	34	28¾

column, but the load may act more on one side of the column than on another; that is, the load may be eccentric, and can induce higher stresses than a greater load acting concentrically. If the column is not at the centre of the area of the floor or other construction supported by the column, the load is eccentrically imposed on it. The safe loads on square interior columns given in *Table* IV are assumed to be concentric but, so long as the eccentricity of the load does not exceed one-sixth of the width of the column, the column can support an eccentric load of five-eighths of the safe concentric load. For smaller eccentricities the safe load is greater, but in no case can it exceed the safe concentric load given in the table.

The loads on columns in external walls and at the corners of buildings are nearly always eccentric, and the safe loads given in *Tables* II and III include reasonable reductions (55 per cent. and 66 per cent. respectively) in the safe concentric load to allow for eccentricities that ordinarily obtain in houses of one or two stories. If a bracket or other projection at the head of a column receives the beam or other member which imposes the load on the column, the tabulated loads would not apply and a special calculation must be made.

The height, size, and shape of a column and the method of fixing the head and base affect its stiffness. A stiff column can support a greater load than one that is less stiff. A tall column is less stiff than a short one; therefore, as is seen in the tables, the safe load decreases as the height increases. The shape of the cross-section of the column can materially affect the safe load; the greater the area for a given shape the stiffer is the column. For equal cross-sectional areas of concrete a hollow column or one having an I-section is stiffer than a solid column, but a solid column is easier to make and is less of an obstruction. The stiffness generally depends on the least width or least breadth of a column, and the larger this dimension is the greater is the safe load in proportion to the cross-sectional area. The shape and size of the column are allowed for in calculating the safe loads given in the tables, but small projections on wall columns forming a rebate for wall slabs are neglected as in such cases the wind forces on the walls are often transferred to the columns. The extra stresses thereby induced are in part off-set by neglecting the extra stiffness, etc., provided by the projections.

Precast Columns.—A column that is fixed so rigidly at both ends that the ends are incapable of even a slight rotation or horizontal movement is stiffer, and will therefore support a greater load, than one that is less rigidly fixed. In precast construction the degree of fixity attained is generally much less than perfect fixity. A column of one story must, however, be fairly rigidly fixed at the base to make it and the structure stable. At the head some restraint will be imposed by adjoining members. For the purpose of the tables, it is assumed that this degree of fixity at both ends is such that the column is as stiff as one of twice the height perfectly fixed at both ends.

Cast-in-situ Columns.—The ends of cast-in-situ columns of one story or passing through two stories, especially if used with cast-in-situ beams and floor or roof slabs, are more rigidly fixed in position and direction than are precast columns, and therefore they are stiffer. The safe load on cast-in-situ internal square columns is therefore about the same as that on a precast column of the same size but of two-thirds the height; for example, the safe load on an 8-in. cast-in-situ column 12 ft. high is about the same as that on an 8-in. precast

column 8 ft. high. In cast-in-situ construction columns are not generally provided in the external walls as the walls themselves support the loads from upper floors and roofs.

Load Imposed on Columns.—The load imposed on a column is the weight of the structure, and loads superimposed thereon, supported by the column, and can be calculated from the weights of the floors, roofs, walls, and similar members comprised in the part of the structure assumed to be supported by the column. The superimposed loads on floors and roofs are generally assumed to be 30 lb. per square foot which, when combined with the weight of hollow or solid concrete slabs as ordinarily used in houses, results in about $\frac{3}{4}$ cwt. for each square foot of floor or roof supported by the column ; this weight includes finishes and beams and the weight of the column. The weights of any walls or partitions should be added. The area assumed to be supported by any one column is a rectangle the sides of which pass midway between the column and each adjacent column.

Roofs.

The roofs of houses are either flat or pitched. Pitched roofs are more generally adopted because the pitched roof is in keeping with the English tradition, and indeed with the tradition of all countries which are subject to snow. Flat roofs have some advantages, such as saving timber, if they are constructed in reinforced concrete. As the recommended superimposed loads on flat roofs are about the same as on the floors of two-story houses, the same thickness of cast-in-situ slab and the same reinforcement as in the upper floors are sufficient. If the external walls are built with blocks, it is advisable to construct a concrete lintel or beam around the upper part of the wall. This beam should be 9 in. or 12 in. deep and the full thickness of the wall, and when it is being concreted small lengths of steel bar of any convenient size should be inserted and left projecting above the top in order to provide attachment for the roof.

For most houses it is not necessary for the thickness of a cast-in-situ roof slab to exceed 4 in. When beams are used they should be over the internal partitions, otherwise they may be unsightly. If the beams are formed above the slab, flat ceilings are obtained and the shuttering is cheaper, but care must be taken to avoid forming troughs from which it will be difficult to drain rain-water. Flat roofs are generally made watertight by a covering of asphalt, bituminous felt or other waterproof material, and it is generally necessary to provide some form of heat insulation.

Examples of flat concrete roofs are given elsewhere in this book together with suggestions for the finish at the outer edges. The concrete may be carried over the wall and project beyond as a cantilever, with reinforcement as necessary, or a blocking-course or parapet may be cast in situ. When the latter is constructed some of the reinforcement from the slabs should be turned up into the parapet, which should be cast as nearly as possible in one operation with the roof slab.

Pitched roofs are occasionally constructed in cast-in-situ reinforced concrete. The sloping sides should be formed as thin slabs, reinforced as already described for upper floors, supported on reinforced concrete purlins carried on the external gable walls. The lower ends of the sloping slabs should be tied across at the head of the concrete walls to prevent an outward thrust being applied to the walls. As the slabs will be visible and form a feature of the building the

exposed face of the slab should be treated by one of the methods described in Chapter VIII.

A pitched roof in reinforced concrete is generally constructed in precast concrete and may consist of precast roof trusses or rafters with purlins supporting lightweight precast concrete slabs, wood-wool slabs, or tiles. Other roofs consist of closely-spaced precast rafters carrying timber battens and tiles, or abutting precast slabs that extend from the eaves to the ridge. Some of these designs are patented. Owing to the complexities at the junctions, a precast roof for a house or a pair of houses should not be hipped, but should have vertical gable ends.

A simple type of precast concrete roof is one in which a truss is formed of two rafters and a steel tie beam. The rafters support precast purlins which, in turn, support the roof covering. The spacing of the purlins depends on the type of roof covering and should not exceed 6 ft. for precast reinforced concrete slabs or reinforced wood-wool slabs. One purlin is placed along the ridge of the roof and one about 3 ft. from the eaves on each slope. Between these positions intermediate purlins should be spaced to suit the lengths of the slabs forming the covering ; this is important as a purlin should be provided under each joint between the slabs. At the eaves the slabs should be attached to a wooden or concrete wall-plate. The size of the purlin depends on the span, that is on the distance apart of the rafters. This span should not exceed 15 ft., but the most economical span is from 6 ft. to 10 ft. depending on the weight of the roof covering. The purlins may be rectangular in section, or, more economically, tee-shaped or ell-shaped. An ell-shaped purlin is stiffer than other shapes for the same weight of concrete ; stiffness is an important requirement in a purlin, otherwise the roof covering becomes distorted. Suitable purlins of proprietary patterns are available. An easily-made purlin is one that has a wedge-shaped section. To span 6 ft. the depth of such a purlin should be $4\frac{1}{2}$ in., and the width 4 in. tapering to $1\frac{1}{2}$ in. at the bottom. The reinforcement should consist of one $\frac{1}{2}$-in. bar placed $\frac{1}{2}$ in. from the bottom, two $\frac{1}{4}$-in. bars placed $\frac{1}{2}$-in. from the top with $\frac{1}{8}$-in binders at 9-in. centres linking the three longitudinal bars together. In the top edge, a wooden nailing strip 1 in. wide by $\frac{1}{2}$ in. deep should be provided for attaching slabs of wood-wool or nailable concrete.

The size of the rafters depends on the spacing of the trusses and the weight of the roof covering. If the trusses are placed at 6-ft. centres, and the distance between the opposite outside walls of the house is 25 ft., the rafters should be about 9 in. deep and 5 in. wide, reinforced with two $\frac{3}{4}$-in. bars in the bottom, two $\frac{3}{8}$-in. bars in the top, and $\frac{1}{4}$-in. binders at 6-in. centres throughout. At the ridge, the two rafters meet at a vertical joint and at the eaves the seating is provided on a cast-in-situ or precast concrete wall-plate or eaves beam. A tie-rod, $\frac{5}{8}$ in. in diameter, should be bolted to, and extend between, the feet of opposite rafters. The sag in the tie-rod can be reduced by providing a suspension rod from the ridge to the mid-point of the tie-rod.

The purlins should be attached to the rafters by two 3-in. by 3-in. by $\frac{1}{4}$-in. steel angle-cleats bolted to the rafters and to the purlin with $\frac{1}{2}$-in. bolts. The four cleats attaching the ridge purlin to the rafters also serve to tie the two rafters together.

Concrete tiles may be used for pitched roofs. They are made in Broseley and interlocking patterns and in a variety of colours. Concrete tiles should be

bought from a reputable manufacturer, and they are laid in the same way as clay tiles. The wooden battens carrying the tiles should be supported on precast concrete rafters placed at 1-ft. 6-in. centres. If an intermediate purlin is provided, as shown in the timber roof in *Fig.* 43, the concrete rafters may be 6 in. deep by 3 in. wide with a ½-in. longitudinal bar near each of the four corners; the longitudinal bars should be bound together with ¼-in. binders at 6-in. centres.

Internal Walls and Partitions.

An internal wall may be a party wall separating one house from the next, a partition carrying the weight of a floor or roof, or a partition that does not carry weight.

A party wall must generally be of the same thickness as the outer walls, except that no cavity need be provided. A proper foundation must be provided. A party wall can be built in solid or hollow blocks without a hard or smooth face, so that they provide a key for plaster.

For partitions in the lower story which support loads from the first floor it is advisable to use solid blocks, similar to those employed in cavity walls. Where it supports cast-in-situ slabs the thickness of a partition should not be less than 4½ in. If two precast slabs meet over a partition it is generally better to provide a reinforced concrete beam not less than 8 in. wide to support the ends of the slabs so that each can have a bearing of at least 4 in. If such a beam is provided at the head of a partition, the partition need not be constructed as a load-carrying wall unless the beam or wall-head depends on the partition for its support. If the beam does not depend on the partition in the lower story for its support, it should be designed to carry the floor and the superimposed load on the floor, and the weight of any partitions in the upper story that come upon it. The depth and reinforcement of such a beam may therefore vary greatly. As an example consider a beam spanning 12 ft. carrying slabs that span 6 ft. on either side of the beam. Such a beam, which can be precast or cast in situ, should be made 15 in. deep and 8 in. wide, with two ¾-in. bars in the bottom, two ½-in. bars in the top and ¼-in. binders at 6-in. centres. This beam could also support a partition.

For partitions which do not carry weight 2-in. or 2½-in. slabs may be used. For partitions on the upper floor it is advisable to use breeze-concrete slabs to make the construction as light and cheap as possible.

It is more satisfactory if partitions on the upper floor are immediately over those below, but when this is not possible effective support must be provided at the level of the first floor to prevent any tendency on the part of the partition to sag and crack. Where the first floor is of concrete ample support is provided, but where a wooden floor is used bridging pieces between the joists are necessary. Wooden-framed partitions are wholly or partly self-supporting, except for the bearings at the ends. A concrete-slab partition must be supported throughout its length, and the support should be sufficiently stiff to prevent deflection when movement takes place on the floor adjoining the partition. Such a support can often be combined with the support for the floor slab in which case the size and reinforcement should be as already described.

The slabs used for partitions should have a groove or joggle on the edges to form a key between adjacent slabs, and they should be jointed with lime

mortar. Where door openings occur in partitions the frames should be built in as the work proceeds, and a small fillet should be attached to the frame to fit into the groove of the slabs on each side to provide lateral support and stiffness. At the top of the opening the slabs are built on the head of the frame, and no lintel is required.

Where supplies of foamed slag are available at an economical price, blocks made with this material are very suitable for partitions. Wood-wool slabs are also being increasingly used for partitions; they are supplied in thicknesses of 1 in., $1\frac{1}{2}$ in., 2 in., and 3 in. Both foamed-slag concrete and wood-wool have good insulation properties, and their surface texture forms an excellent key for plaster. Bricks made with breeze concrete may be used for partitions $4\frac{1}{2}$ in. thick, but as concrete bricks are made in the same sizes as clay bricks there is no saving of labour.

Methods of making some of the precast products used in houses are described in Chapter VI.

Staircases.

Concrete is suitable for staircases, as it is strong, cheap, and hygienic, and it can be easily adapted to any position or type. The staircase may be cast in situ, or built in precast steps. When cast-in-situ reinforced concrete is employed for the walls and floors the same material is sometimes used for the staircase, the reinforcement from which is carried into the floors or other adjacent work. The complicated shuttering required, however, often offsets the advantage of having a monolithic structure, and for this reason precast stairs are generally preferable whether the walls are constructed in situ or with precast blocks. Stairs may be precast as separate steps or as a complete staircase.

A staircase may be supported by two parallel stringer beams, it may be entirely carried by partitions, or one edge of the stairs may be supported by a partition and the other by a stringer beam. If it is precast in one piece or if it is cast in situ, a staircase may not require support along the two sloping edges; in this case the staircase spans from a foundation at the level of the ground floor to a landing or beam at the level of the first floor. If intermediate landings are provided at which the stairs change direction, or if there is a wind in the staircase, the construction is more complex, and such staircases are not generally suitable for precasting in one piece; each flight can be precast separately, or each step separately; or the whole staircase with the intermediate landings can be conveniently cast in situ.

With cast-in-situ concrete the least thickness, which occurs at the inner junction of the tread and riser, called the waist, should be not less than 2 in. if the stairs span between two stringer beams. The stringers should be formed as straight sloping beams parallel to the slope of the stairs, except where winders occur, and here they will be curved. Reinforcement for each stringer should generally comprise one $\frac{3}{4}$-in. bar in the bottom and one $\frac{1}{2}$-in. bar in the top linked together with $\frac{3}{16}$-in. binders at 6-in. centres. Across the width of the flight, one $\frac{3}{8}$-in. bar should be placed in the bottom of each step. It is often convenient for the soffit of the stringers to be flush with that of the steps, in which case the stringer, about 3 in. wide, will project sufficiently above the level of the steps to cover the nosing. This method requires less complicated shuttering than when

the stringer projects below the steps. A method of constructing the shuttering for a staircase, which is supported partly on walls and partly on stringers, projecting about 2 in. below the soffit of the stairs, is shown in *Fig.* 76. This type of staircase with a half-landing is common in houses. The shuttering should not present any difficulty to a good carpenter. When the depth of the stringer

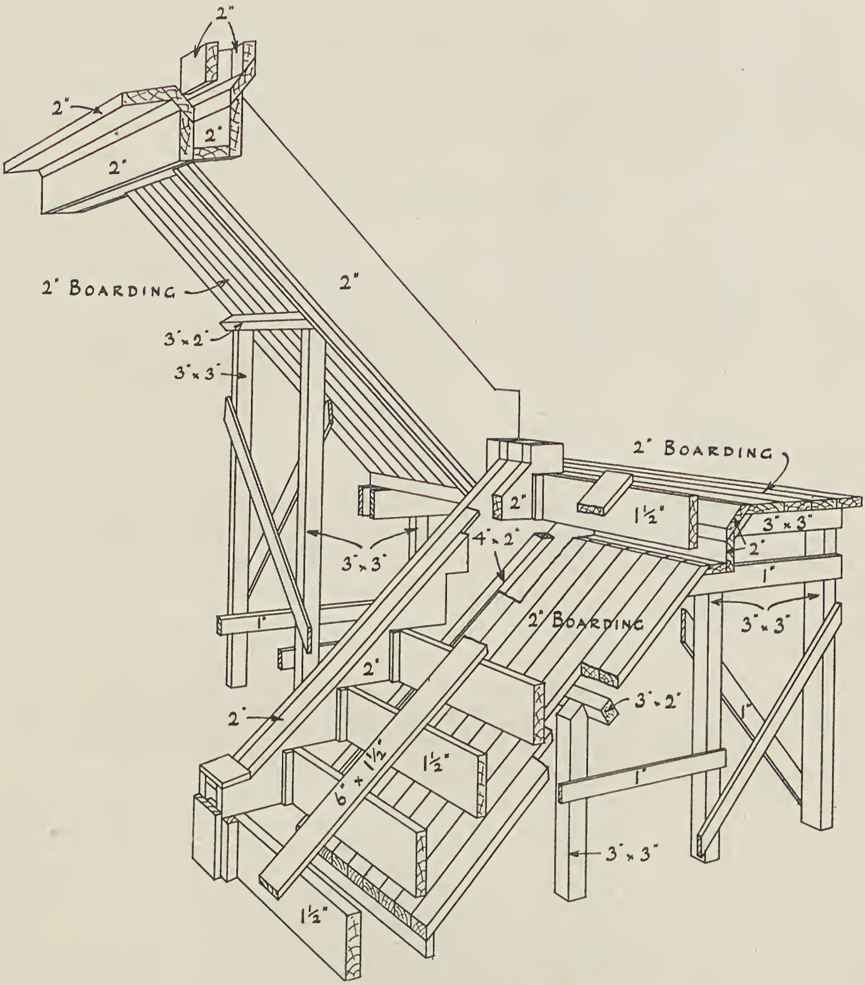


FIG. 76.—SHUTTERING FOR STAIRS.

exceeds the width of a single board, the shuttering for the outer face of the stringer is formed with 2-in. longitudinal boards connected with battens.

If the stairs span from top to bottom, in which case stringers are unnecessary, the thickness of the waist must be increased, as the strength of the staircase is then dependent on this thickness, which is generally sufficient in a house if it is $4\frac{1}{2}$ in. The reinforcement depends on the span, but in an ordinary house $\frac{3}{8}$-in. bars at 6-in. centres from top to bottom of the flight and $\frac{1}{2}$ in. above the

soffit of the stairs are satisfactory. This method seldom occurs in houses, and it is not generally economical except for very short flights.

When concrete stringers are used to support precast steps they should have a projecting ledge of concrete cast on the bottom edge to form a bearing for the steps. It is often more convenient to precast the stringers than to construct them in situ.

Very light precast or cast-in-situ staircases can be constructed by forming the stringers, treads, and risers in reinforced concrete slabs about 3 in. thick. The reinforcement generally consists of one ½-in. bar across the width of the flight at the bottom of each riser with ¼-in. bars, wired to it, bent to the shape of the steps and about 9 in. apart. Less concrete is employed than with solid steps, but the shuttering is more complicated as the risers require to be moulded between two vertical faces of shuttering. If they are cast in situ the treads will need shuttering only on the underside.

Precast steps should be made with the soffit parallel to the pitch of the staircase, as this makes a neater finish and uses less concrete than solid square steps. A square end for the width of the bearing can be formed when the steps are to be built into partitions, as this makes a better bearing and avoids waste and cutting of the partition blocks. A splayed rebate or "back joint" should be formed at the bottom of each riser to give a bearing on the step below. Reinforcement is sometimes placed in the steps but is not necessary unless the steps are exceptionally long. Cantilevered steps must be reinforced with bars in the upper part, but generally the underside of the staircase will be enclosed to form a cupboard or coal store and bearings at both ends of the steps are easily obtained.

Landings should be provided with reinforcement near the underside. If landings are cast in situ only a few plain boards are necessary for the shuttering. The amount of reinforcement depends on the method of supporting the landing and on whether the landing supports one end of one or more flights of stairs. If the stairs are supported independently and a landing 9 ft. long and 4 ft. wide is supported by walls on two short sides and one long side, the reinforcement in the bottom extending between the supports on the two short sides should be ⅜-in. bars placed at 6-in. centres with ¼-in. cross-bars at 9-in. centres.

The surface of concrete steps should be hard wearing unless they are to be covered with carpet. For treads subject to exceptionally hard wear the best material is a mixture of 1 part of Portland cement and 3 parts of granite chippings. This finish should be about 1½ in. thick, and in the case of in-situ concrete should be applied while the concrete is green to prevent separation, and in the case of precast steps it should be applied at the time of moulding. The surface may be roughened when required by forming grooves or indentations with a suitable tool, with a steel comb, or by pressing a lath into the wet concrete. To improve the wearing properties of ordinary concrete a solution of 1 part of silicate of soda to 4 parts of water is sometimes applied to the surface with a brush after the concrete has hardened. Generally a less expensive wearing surface than granolithic is sufficient, and a suitable finish can be obtained by trowelling granite chippings into the surface of the concrete while it is still wet. Generally only doorsteps require such treatment.

If there is a partition wall on one or both sides of a staircase, it is a simple matter to fix a wooden handrail on small iron brackets attached to the partition,

and no balusters are required. When balusters are necessary they may be of plain square iron, as these can be let into the concrete, or, if wooden balusters are used and there is a concrete string, a continuous wooden cap can be screwed to plugs in the concrete and the bottom of the balusters housed into the cap.

A design for a staircase is given in *Fig.* 77 where precast concrete steps are built in as the work proceeds. A moulded nosing to the tread is liable to be damaged and has been replaced by a plain splayed face to the riser with a rounded top edge. The steps should be cast with square ends to give a bearing and avoid the use of blocks of triangular shape in the walls and partitions. Illustrations of precast steps are given in *Figs.* 77 and 78, the latter showing a step with a slight nosing.

Door and Window Frames.

Details of reinforced concrete frames for doors and for windows with metal casements are given in *Figs.* 79 and 80. These are for houses built of precast blocks; in the case of in-situ walls the frames would be formed with the walls.

The frames are easy to make, as there are no elaborate mouldings. In connection with the windows (*Fig.* 80), an inner sill of concrete is shown and the

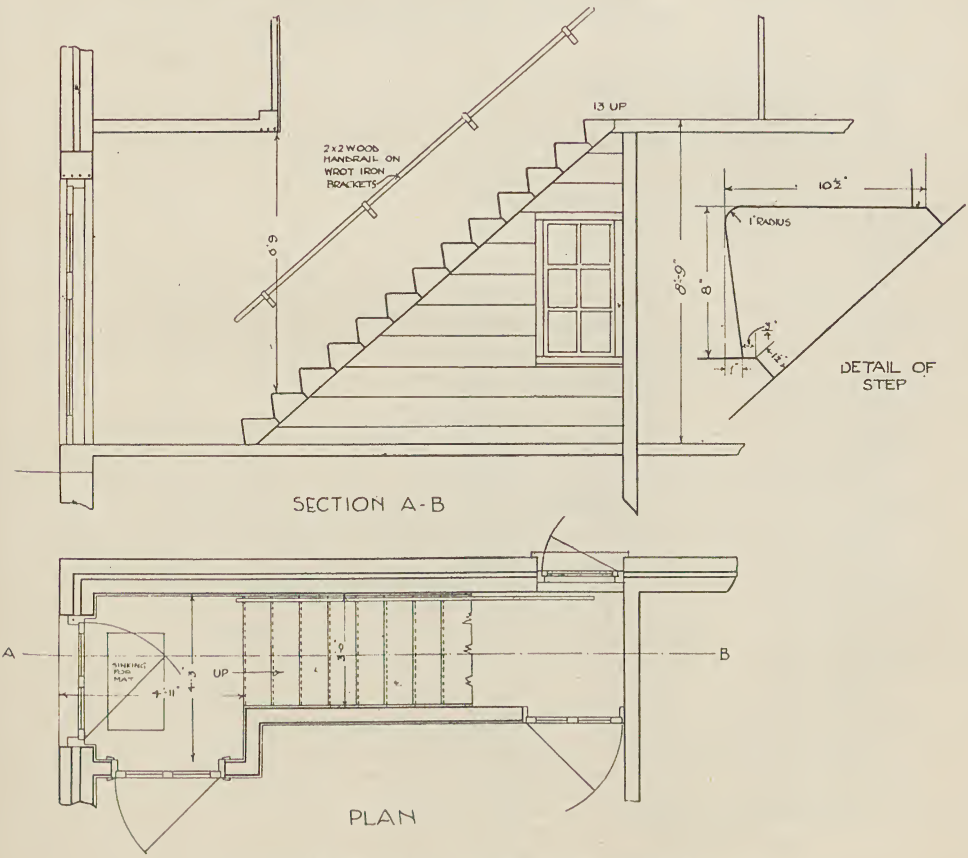


FIG. 77.—DETAIL OF STAIRCASE WITH PRECAST STEPS.

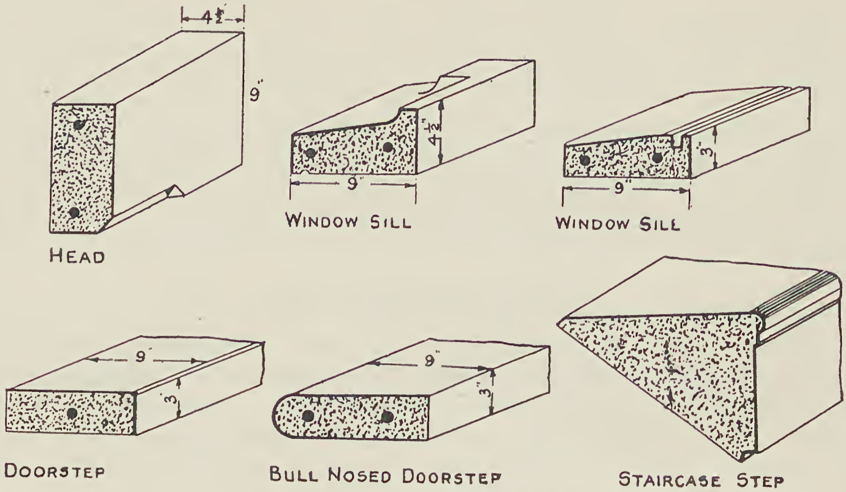


FIG. 78.—SILLS, STEPS AND HEADS.

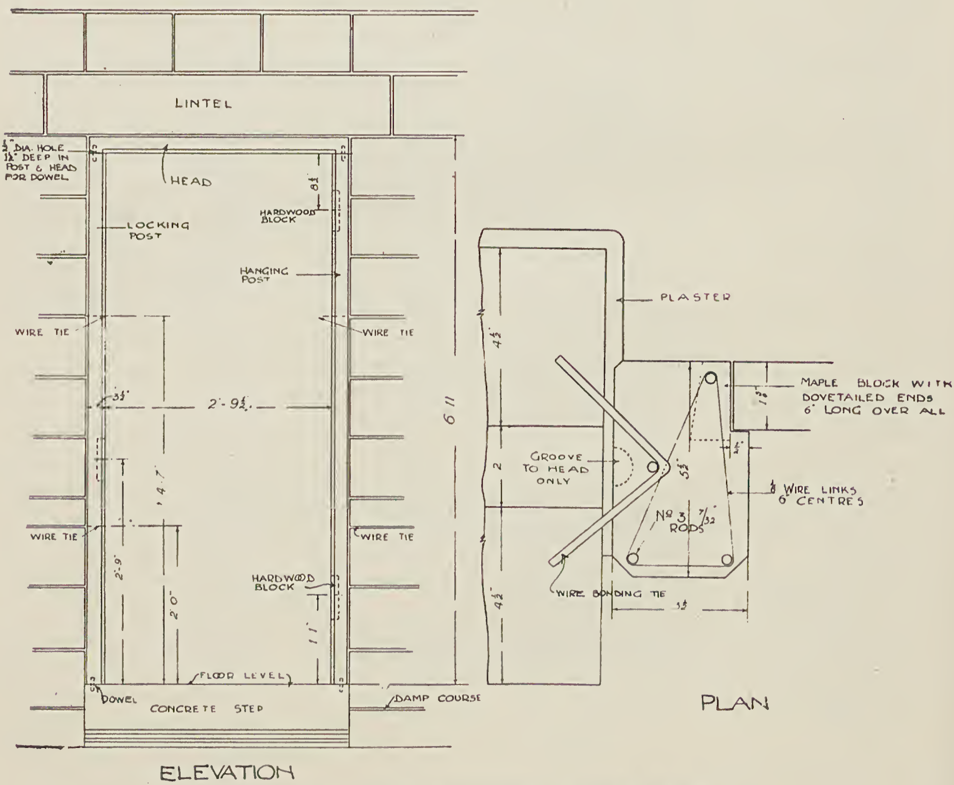


FIG. 79.—DETAIL OF CONCRETE DOOR FRAME.

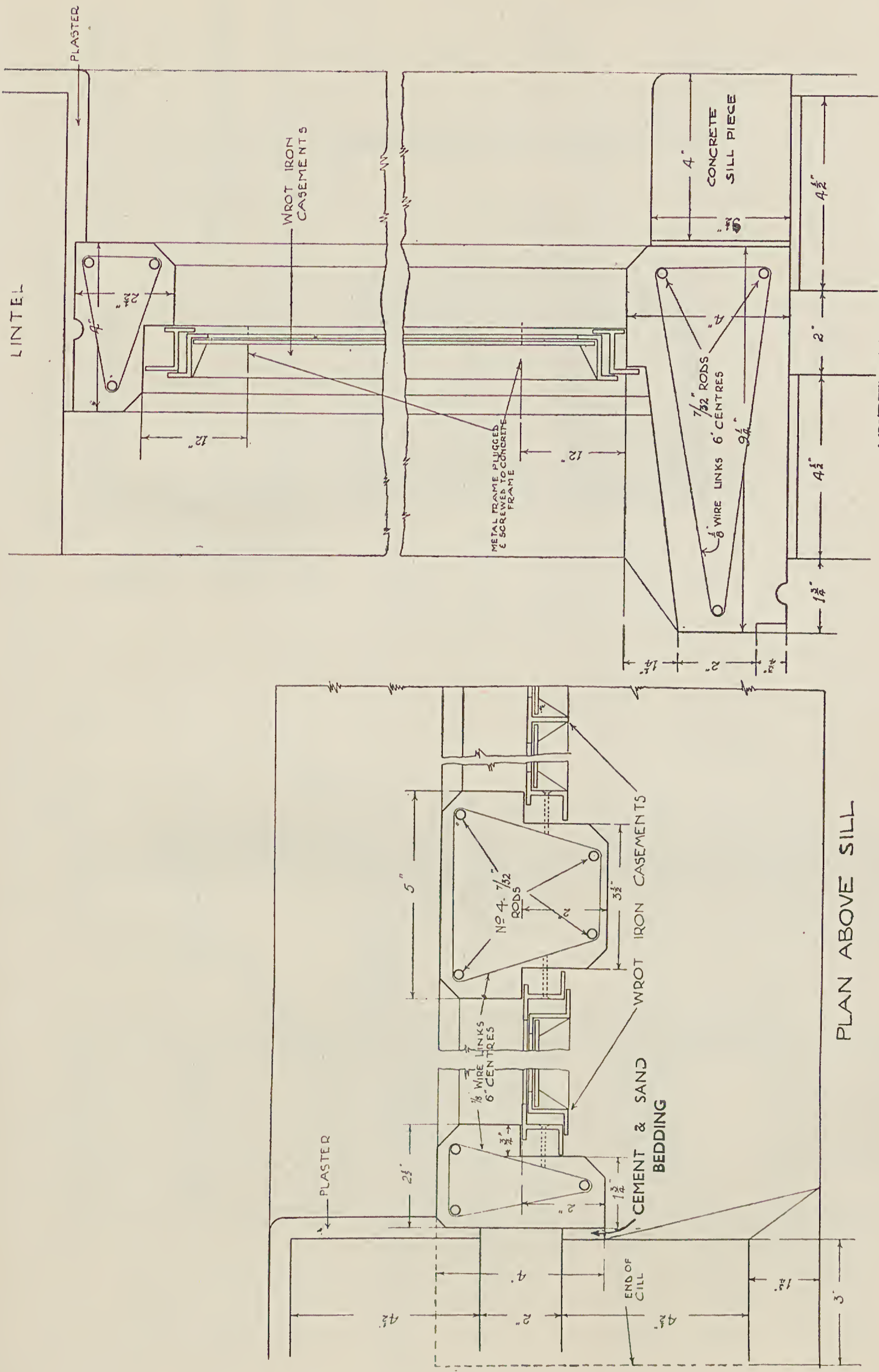


FIG. 80.—DETAILS OF CONCRETE WINDOW FRAMES AND SILLS.

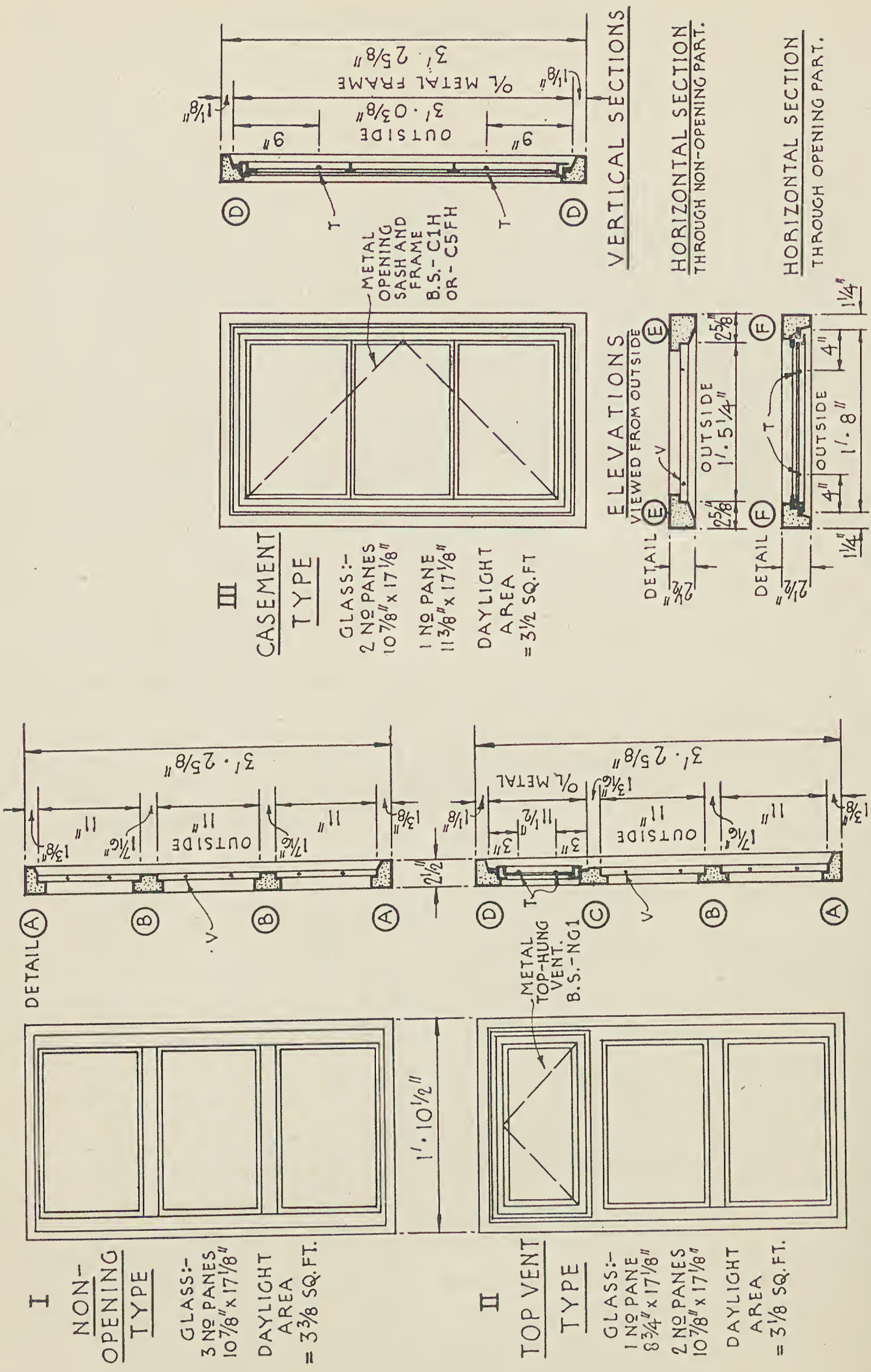


FIG. 81.—PRECAST CONCRETE WINDOW FRAMES.

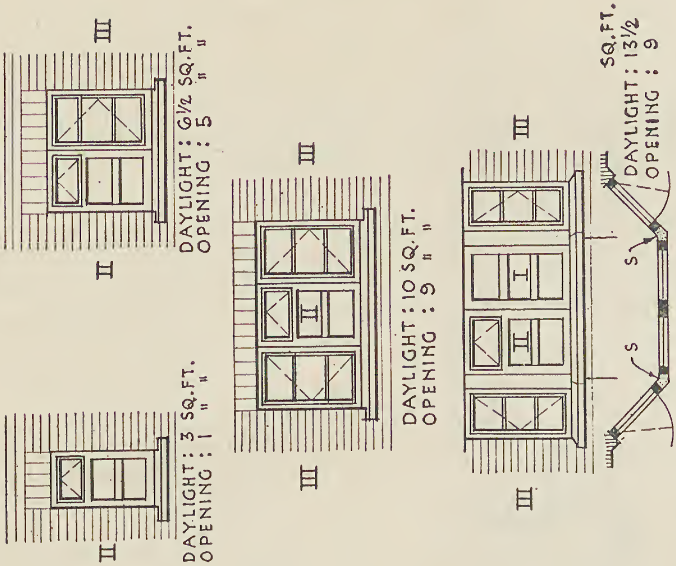


Fig. 83.—Typical Assemblies of Concrete Window Frames in Walls of Concrete Bricks (or Blocks).

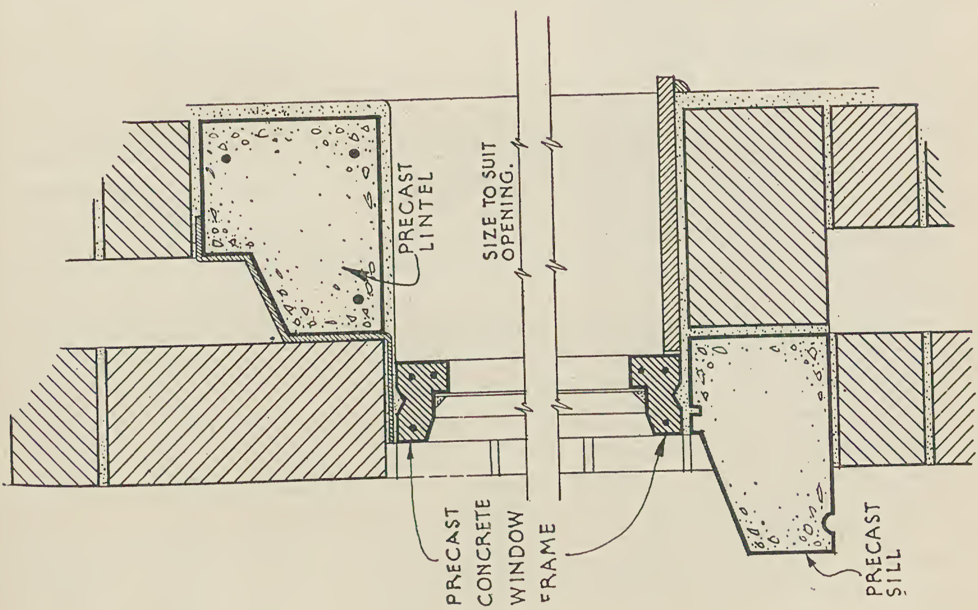


Fig. 82.—Details of Head and Sill in wall of Concrete Bricks.

jambs are finished in plaster carried to the concrete frame; the use of joinery is entirely eliminated. Wooden sashes can, however, be used with the concrete frames if preferred. The various precast pieces should be built in as the work proceeds in order to obtain the best fixing.

In the case of the door frames, ties are cast into the side posts with projecting ends built into the joints as indicated in *Fig.* 79, while provision for fixing ironmongery is made by the insertion of dovetailed hardwood fixing blocks. The type of frame shown has been successfully used by the writer in houses with concrete walls.

In *Figs.* 81 to 85 other window frames are shown. The overall height conforms to a whole number of concrete-brick courses and the overall width conforms to sizes of concrete bricks. These overall dimensions assume a $2\frac{5}{8}$-in. brick of concrete and should be altered if bricks or blocks of other dimensions are used.

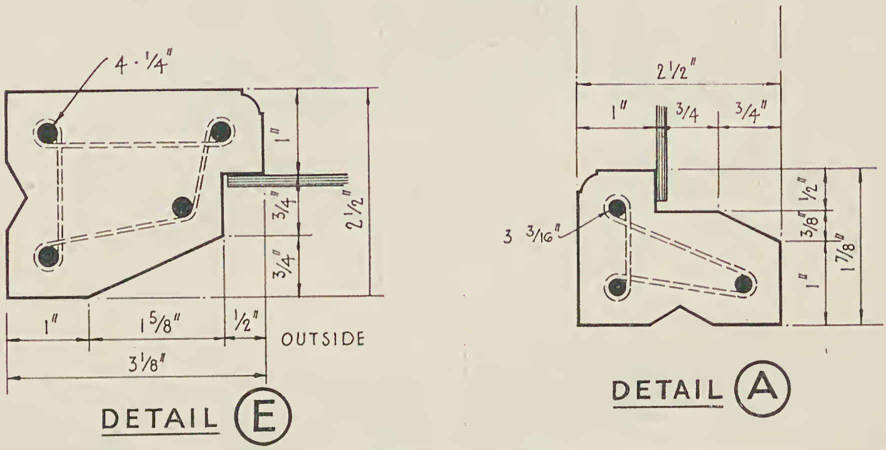


Fig. 84.—Sections of Members of Concrete Window Frames.

In *Figs.* 84 and 85 sections of the various parts are given. The dimensions are arranged so that the same moulds can be used, with a minimum of adaptation, for both opening and non-opening types. Where precautions are taken to ensure high-quality concrete and freedom from damage while being transported, handled, and erected, experience may show that the dimensions given can be reduced slightly.

Although some opening-type windows have been successfully made entirely in precast concrete, this design does not readily lend itself to mass production. Therefore, in the designs illustrated, opening parts are provided by building-in metal windows with either top-hung vents or side-hung casements. The metal frames can be laid in the moulds before concreting, thereby ensuring complete fixity between the metal and the concrete. Additional fixing can be obtained by providing metal lugs at each screw-hole (T), *Fig.* 81.

Alternatively the metal frames may be fixed in position after erection of the concrete frames, in which case the cross section of the concrete members should conform to the broken lines marked R (*Fig.* 85), thereby allowing a clearance for pointing after erection. To take the fixing screws, $\frac{5}{8}$-in. diameter hardwood plugs P (*Fig.* 85) $1\frac{1}{4}$ in. long are inserted in the concrete at each position

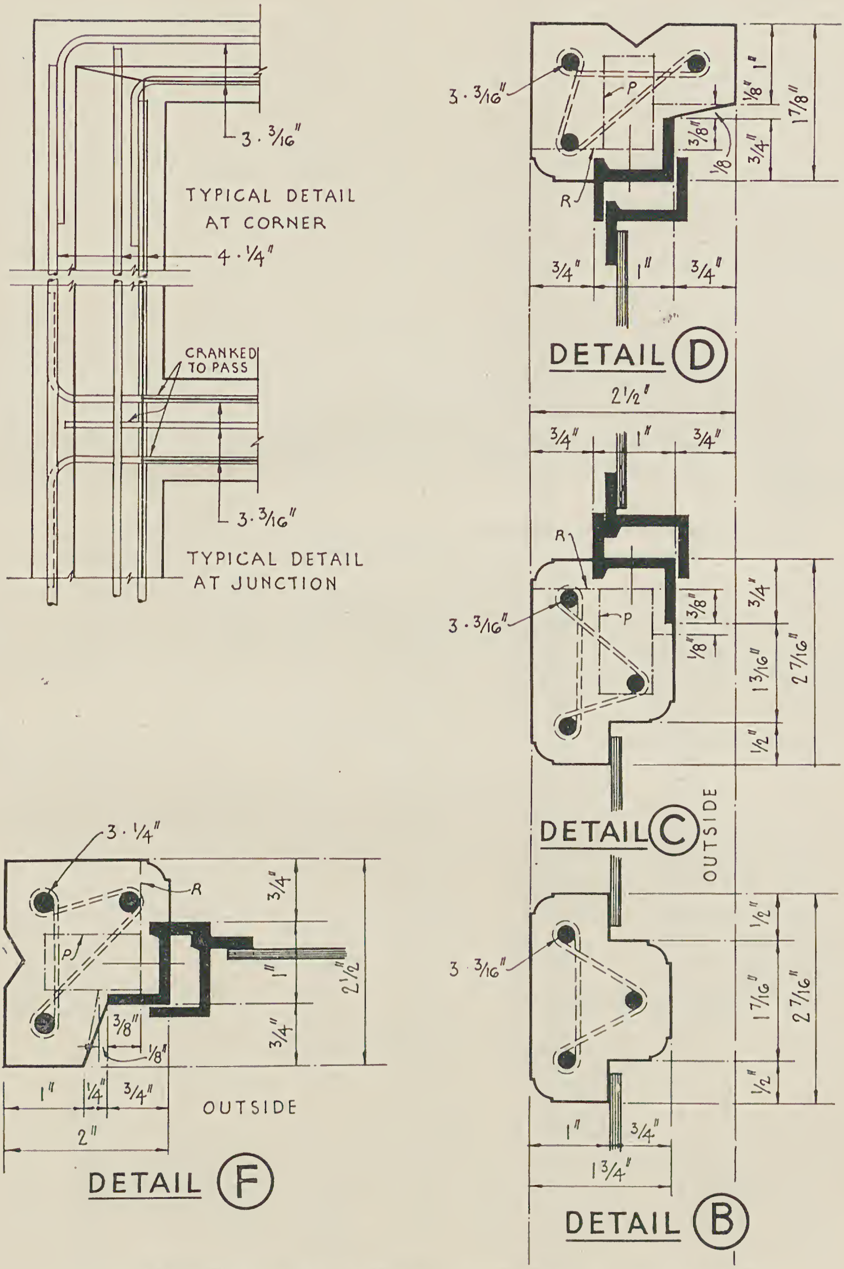


Fig. 85.—Sections of Members of Concrete Window Frames.

marked T (*Fig.* 81). It is important to make sure that the positions of the plugs at T coincide with the positions of the screw-holes in the metal frames to be built into the concrete frames. It is necessary to adjust slightly the arrangement of the reinforcement if the section indicated by R is adopted. It is not recommended that the metal window in type III should be fixed after casting unless the dimensions of the concrete side members are increased.

The sizes of the panes of glass given in *Fig.* 81 show that panes $17\frac{1}{8}$ in. wide only are used, in heights of $8\frac{3}{4}$ in., $10\frac{7}{8}$ in., and $11\frac{3}{8}$ in., which are the sizes required for the standard metal windows. With concrete window frames, as with metal, it is necessary to use mastic in place of linseed-oil putty when glazing. In the non-opening portions, small holes, say $\frac{1}{8}$ in. diameter and $\frac{1}{2}$ in. deep, should be formed in the positions marked V to take glazing sprigs.

The reinforcement required is shown in *Figs.* 84 and 85. The overlaps at corners and junctions should be securely tied or welded together. The steel should be rigidly supported in the moulds to give not less than $\frac{3}{8}$ in. nor more than $\frac{1}{2}$ in. cover of concrete; accuracy is best obtained by providing binders of $\frac{1}{8}$-in. diameter mild steel (or the equivalent in cold-drawn wire) spaced at about 6-in. centres. The binders can either pass around the bars as shown, or be secured by welding.

Fig. 82 shows a precast window frame erected in a wall with standard precast concrete sills. Owing to the strength of the frame and the small span, a lintel immediately over the frame is not always necessary, although a precast concrete lintel of sufficient size to span the clear opening is required to carry the inner leaf of a hollow wall or the extra thickness of a solid wall. The " check " along the sides, bottom, and top of the precast window frame should be noted (*Figs.* 82, 84 and 85).

Windows suitable for various rooms are illustrated in *Fig.* 83. To comply

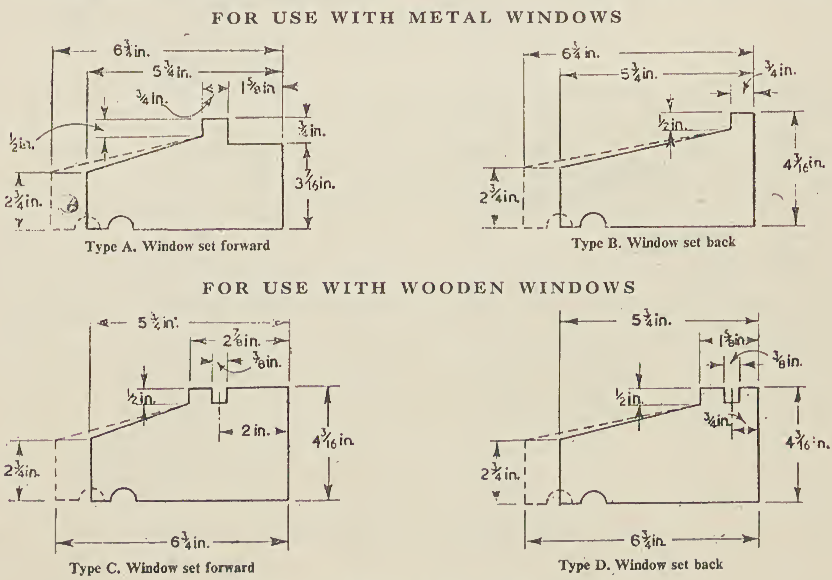


FIG. 86.—PRECAST CONCRETE SILLS.

with most by-laws it is necessary to have a daylight area of window equal to 10 per cent. of the floor area of each room. For guidance in this respect, the clear areas of glass for each type of window are given in *Fig.* 81, and in *Fig.* 83 the gross daylight area for each window is indicated, together with the area of the opening. The opening is required by by-laws to be 5 per cent. of the floor area of each room. In practice much more than the required minimum area of daylight and opening is generally provided.

In bay windows a splayed mullion, marked S in *Fig.* 83, is necessary. The ends of the mullion should be shaped to suit the sill and lintel, and provision should be made for securing the mullion.

Concrete window frames for special purposes can be devised by alteration of the details shown.

Lintels and Sills.

Window and door heads, or lintels, should be precast and reinforced. Where the distance between the supports is not more than 4 ft. 6 in. two $\frac{3}{8}$-in. bars are enough, but the lintel must have a bearing of at least $4\frac{1}{2}$ in. at each end, and in some cases where the heads are used with concrete blocks a bearing of 9 in. is given at each end. If the opening is larger than 4 ft. 6 in. more reinforcement

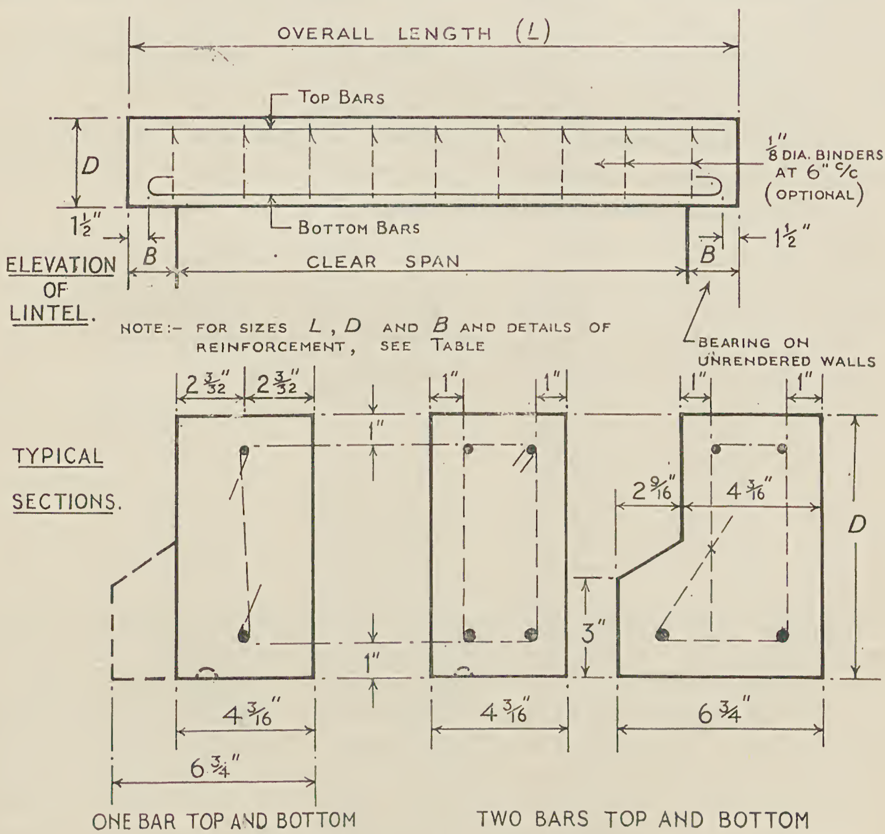


Fig. 87.—Precast Concrete Lintels.

will be required. The depth of the lintel used in a concrete block wall is generally $8\frac{5}{8}$ in., which is the same depth as one course of blocks. A section through a lintel showing the position of the reinforcement is given in *Fig.* 87. *Fig.* 78 shows some typical sills and doorsteps which are generally bedded on the walls or upon blocks and only need reinforcement so that they can be handled without breaking. In *Fig.* 86 the British Standard dimensions of sills suitable for use with metal or wooden windows are given. The lengths may vary from about 1 ft. 3 in. to about 8 ft. 3 in., depending on the size of the window with which the sills are used. If the length required is made up of a number of short pieces of precast sill, reinforcement is unnecessary.

The length of stooling at each end should be 2 in. and in the case of sills for steel windows dowel holes, $\frac{3}{4}$ in. diameter and $1\frac{1}{4}$ in. deep, should be provided. The alternative widths given in *Fig.* 86 are for sills for use on unrendered walls ($5\frac{3}{4}$ in.) and rendered walls ($6\frac{3}{4}$ in.).

Sizes of precast concrete lintels are shown in *Fig.* 87. For use with metal windows the lengths may be from 1 ft. $9\frac{1}{2}$ in. to 7 ft. $9\frac{1}{2}$ in., and for use with wooden windows from 2 ft. $2\frac{1}{2}$ in. to 8 ft. $11\frac{1}{2}$ in. Other lengths are required for lintels over metal or wooden doors.

Lintels with a throating or drip are for use in the external leaf of cavity walls or on the outer face of hollow block walls or 9-in. brick walls. Those with a projection are for use in the inner leaf of cavity walls. Those with neither projection nor drip are for use on the inner face of hollow block walls or 9-in. brick walls.

The reinforcement required for load-carrying purposes, as well as for handling, are given in *Table* V. These quantities are suitable for lintels in ordinary house

TABLE V.—REINFORCEMENT AND DIMENSIONS FOR CONCRETE LINTELS.

Total length L		Depth D	Mild steel reinforcement			
			Bottom bars		Top bars (for handling purposes only)	
Ft.	In.	In.	No.	Diameter (in.)	No.	Diameter (in.)
2	6	$5\frac{5}{8}$	1	$\frac{5}{16}$	1	$\frac{1}{4}$
3	6	$5\frac{5}{8}$	1	$\frac{3}{8}$	1	$\frac{5}{16}$
4	0	$5\frac{5}{8}$	2	$\frac{5}{16}$	2	$\frac{1}{4}$
5	0	$8\frac{5}{8}$	2	$\frac{5}{16}$	2	$\frac{1}{4}$
6	0	$8\frac{5}{8}$	2	$\frac{3}{8}$	2	$\frac{5}{16}$
7	0	$11\frac{5}{8}$	2	$\frac{3}{8}$	2	$\frac{5}{16}$
9	0	$11\frac{5}{8}$	2	$\frac{1}{2}$	2	$\frac{3}{8}$

construction. Lintels subject to abnormal loads should be specially designed. The provision of top reinforcement for increasing the strength for load-carrying is not generally economical, since a large number of closely-spaced binders is then required to enable the top bars to be effective. Binders are not otherwise always necessary, but their use enables the whole of the bars for one lintel to be made up into a cage, which is placed in the mould and secured in position to give the required cover of concrete over the main bars. The latter must be spaced symmetrically about the vertical centre-line of the section where possible, although one bar off-centre is advisable in lintels for the inner half of cavity walls.

Since the top bars are generally much lighter than the bottom bars, it is essential that the top face of lintels should be indelibly marked "TOP," thereby ensuring that the lintel will be placed in its correct position.

Three depths of lintels are given to suit $2\frac{5}{8}$-in. clay or concrete bricks with $\frac{3}{8}$-in. joints ; if other bricks or blocks are used the sizes of the lintels can be altered accordingly.

Chimneypieces.

Precast concrete is very suitable for the construction of chimneypieces, as several finishes are possible provided a suitable aggregate is used and a good surface is obtained. *Fig.* 88 shows a design suitable for a living-room where the mantelshelf is high and is supported on concrete blocks ; the blocks can be rectangular or moulded. *Fig.* 89 indicates a type suitable for a parlour or bedroom. The firebrick back and a well-type grate would be of standard size, and tile surrounds or other features are unnecessary. Many manufacturers of precast products make concrete fireplace surrounds in one piece and without a projecting

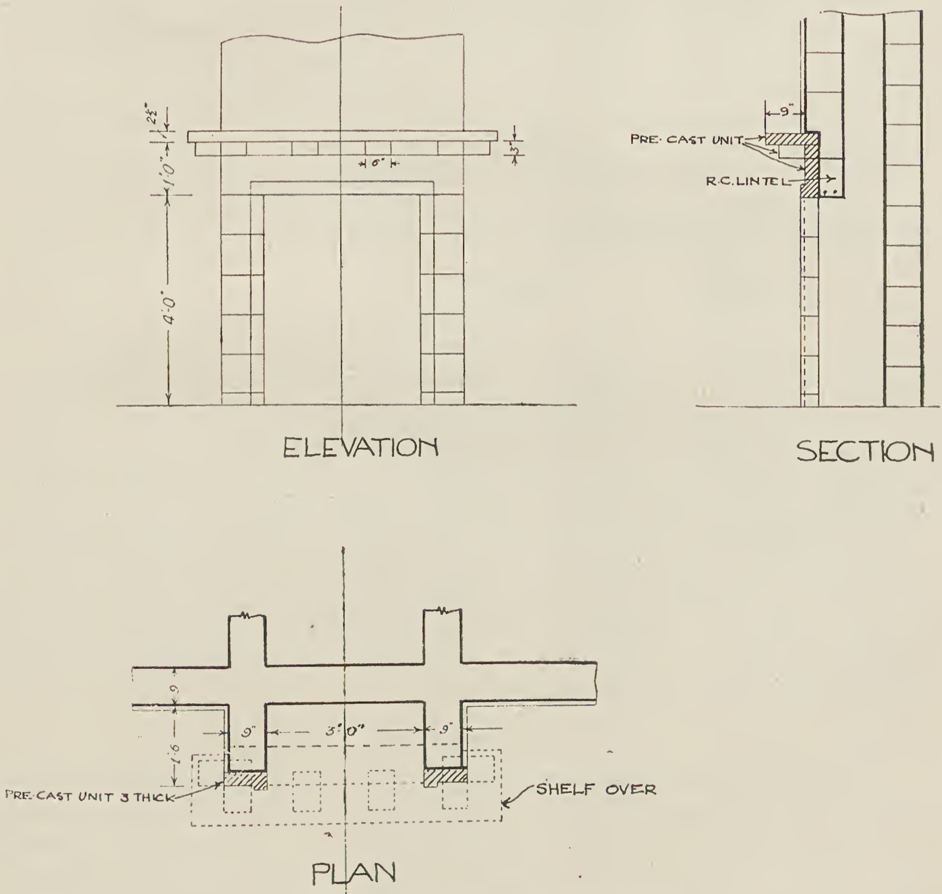


FIG. 88.—CHIMNEYPIECE IN LIVING-ROOM.

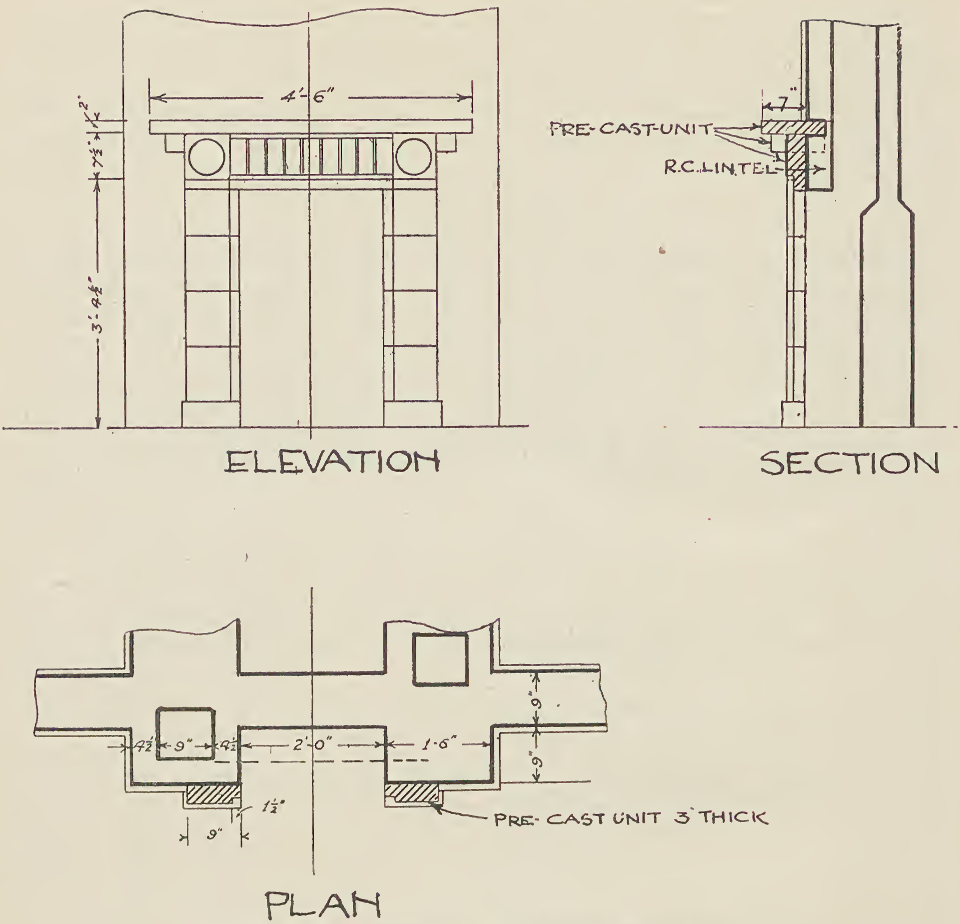


Fig. 89.—Chimneypiece in Parlour or Bedroom.

mantleshelf, and it is generally possible to purchase a chimneypiece ; this is cheaper than having a few chimneypieces made to a special design.

For building chimney-breasts and similar features inside a house, the walls of which are to be plastered, it is recommended that concrete bricks, which are the same size as ordinary burnt-clay bricks (nominally 9 in. by 4½ in. by 3 in.) be used as they are adaptable to a feature of irregular shape and size without the need for making special blocks. A small stock of concrete bricks should be kept on the site for use as required.

Bay Windows.

A detail of a bay window is shown in *Fig.* 37. The roof is formed by a small concrete slab 6 in. thick having a raised portion reinforced with four ½-in. bars at the inner edge to form a lintel for carrying the wall. The rainwater is drained into a groove around the outer edge and carried away by a 2-in. downpipe as indicated. The outlet for the pipe is cast in when the slab is concreted ; no flashing is then necessary.

Joinery and Fittings.

The joinery and fittings should be as simple as possible, elaborate mouldings being avoided as they harbour dirt. Doors should be of uniform width and height, the dimensions over the frames being a multiple of the size of a block when blocks are used in construction, or of stock size when blocks are not used. The windows should be limited to one, two, or three sizes according to requirements, and if made of wood they should also conform to the dimensions of concrete blocks. The area of the daylight opening of the window should be based on the area of the floors, the rule being that the total area of the window or windows, clear of the frames, shall be equal to one-tenth the area of the floor of the room. At least half of each window should be arranged to open, but it is preferable to be able to open the whole of the window.

Pipes should preferably be kept on the surface of the walls, and when these are unsightly they may be enclosed with plain wooden casing fixed with screws for easy removal. When butts are provided for the storage of rainwater they should stand on plain concrete blocks to raise them above the ground, as this will render them less liable to decay. Concrete rainwater tanks are more durable and hygienic, and can be economically manufactured by precasting.

A small paved area is always advisable at the rear of a house, and this can be provided by an in-situ layer of concrete 4 in. thick finished with wooden and steel floats as described for floor surfaces. Alternatively the area can be paved with concrete flags or similar precast concrete slabs. Paths can also be paved with concrete either as a solid slab or as crazy paving.

Other uses for concrete outside a house include precast clothes-line posts, fences of many types, coal-bins, rubbish-bins, greenhouses, and various other products for gardens.

Plastering.

In the case of plastering, only a skimming coat will be required on concrete walls and ceilings in the principal rooms, while in sculleries and similar places no plastering at all will be required and distemper can be applied directly to the concrete. The soffit and jambs around windows can be plastered to give a clean surface continuous with that of the walls without the introduction of architraves. Window boards can be dispensed with and red quarry-tiled sills substituted; these are easily cleaned, do not mark, and do not require painting.

CHAPTER VI

MANUFACTURE OF PRECAST CONCRETE PRODUCTS

Concrete dressings such as sills and window and door frames, and concrete beams, steps, and other concrete products used in houses, are best bought from a firm specializing in the manufacture of these products, but if they cannot be so obtained they may be made on the site. It is seldom, however, that the same quality or surface finish can be obtained if the products are made by men inexperienced in the work.

If it is desired that the products should resemble natural stone the exposed faces to a thickness of 1 in. should be made of concrete in which the aggregate comprises the stone it is desired to match and in which the cement is of the same hue. Ready-coloured cements may be purchased suitable for matching some stones, but in other cases it may be necessary to add a mineral pigment to ordinary or white Portland cement. Where a special concrete is used for the face it is best to use a mould in which the face of the product is at the bottom, the special concrete being placed first and followed by ordinary concrete. Generally the aggregate for matching natural stone should not exceed $\frac{1}{4}$ in. in size, depending on the texture of the surface of the stone it is desired to match. If ordinary concrete is used throughout the maximum size of the aggregate should generally not exceed $\frac{3}{8}$ in., and the same size aggregate is suitable for the remainder of a product with a special face. The proportions for special face mixtures should be 3 parts of aggregate to 1 part of cement. For ordinary concrete the proportions should be from 3 to 4 parts of aggregate graded from $\frac{3}{8}$ in. down to 1 part of cement.

In this chapter are given designs for moulds for a number of concrete products used in and around houses. Complete details of every mould are not given as this would result in unnecessary detail and repetition, but it is hoped that sufficient information is given to enable the reader to design a mould for any of the concrete products commonly used in small buildings.

Generally the timber should not be less than 1 in. thick; the sides of the moulds should preferably be 2 in. thick in order to avoid the need for transverse ties to prevent them bulging under the pressure of wet concrete. Moulds must be made accurately to shape and size, and it is best to soak them in water before use and scrape off any bulges that appear when the wood is wet. If smooth surfaces are wanted the wood should be rubbed with glass-paper. Any screws driven into a working face should be countersunk and the heads filled with putty or plaster. A non-staining mould oil should be applied to the working faces, and after each use the moulds should be cleaned and oiled again. If mould-oil is not available, limewash will serve the same purpose of preventing the concrete

from sticking to the wood. The useful life of a mould is prolonged if the working faces are waterproofed by two or three coats of white-lead paint or shellac. If a large number of castings is wanted it may be best to line the inside of the moulds with sheet metal.

Some methods of fixing the parts of moulds are shown in the drawings, but other methods may be used so long as they make the mould rigid and allow it to be easily removed without damaging the mould or the casting. Where the shape of the product permits it is best to dispense with a bottom to the mould and to make the product directly on a smooth and level bench or floor which

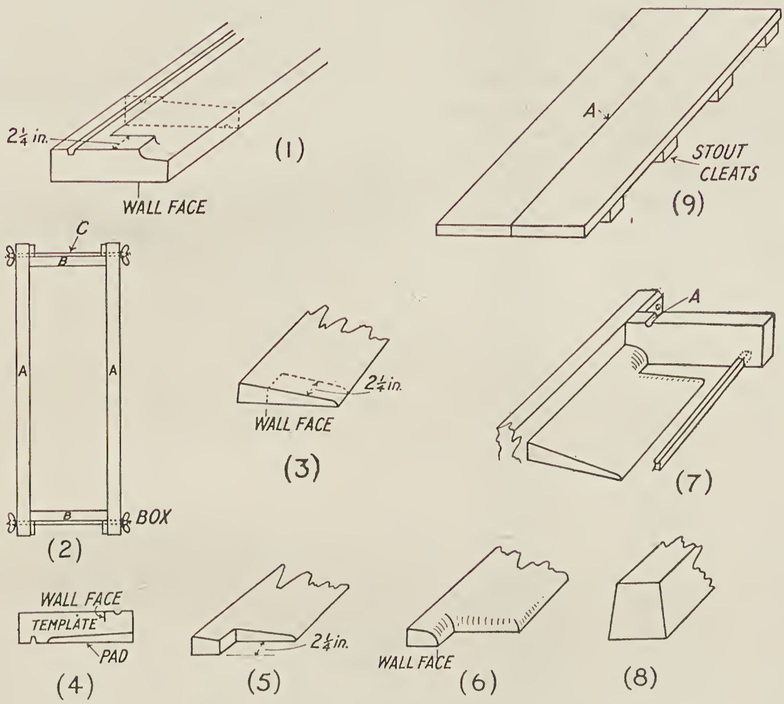


FIG. 90.—MOULD FOR WINDOW SILL.

has been oiled, or covered with stout paper, to prevent adhesion ; if this cannot be done a wooden pallet may be used in the bottom of the mould, so that the mould can be removed for use again and the product carried on its pallet to the place where it is to harden, or a board may be placed over the mould and the whole turned over. Plaster, concrete, and gelatine moulds are also used for making concrete products, but these are outside the scope of this book.

SILL (*Fig.* 90).—A common size for a sill is 3 ft. long (including two $2\frac{1}{4}$-in. stools) by $7\frac{1}{2}$ in. wide by $3\frac{1}{2}$ in. deep. The drawings show a mould for a sill of these dimensions, but they can be altered to make sills of different sizes. A zinc or plywood template as shown by dotted lines in drawing (1) is made first, and on this the positions of the wall face and the groove to take the weather-bar are marked. At (2) is shown a plan of the mould box. The sides (A) should

be about 3 ft. 9 in. long by $3\frac{1}{2}$ in. deep. The ends (B) are $3\frac{1}{2}$ in. deep by $7\frac{1}{2}$ in. long, and are held in position by cleats fixed to the sides. The mould is held rigidly together by bolts with wing nuts as shown, and these should be close to the ends, so that they will not cause the sides to bend when the nuts are tightened. Four thumb-bolts are used to hold the sides and ends to the bottom; these pass through the bottom and are screwed into sockets in the bottom edges of the sides and ends. The pallet (9) is made of 1-in. boards on 3-in. by 2-in bearers or cleats. The pad is shaped to fit the template as at (4). The method of forming the stools is shown at (3), (5), and (6). The position of the wall face is first marked on the pad and the stool is set out as at (3), cut out as at (5), and finished as at (6). The pad is then fixed to the pallet by wood screws from the underside. A strip of wood of the required size to form the groove to take the weather-bar is cut a few inches longer than the overall length of the mould, passed through openings cut in the ends, and nailed to the pallet as at (7). The water-drip is formed by tapping a strip of wood into the grooves in the ends as shown at (A) and into the concrete after the sill has been cast.

Lintels (*Figs.* 91 and 92).—In the case of the internal lintel (*Fig.* 91), the ends (A) are fixed to the sides (B) with thumb-bolts, and thumb-bolts are also used for fixing the sides to the bottom. The inserts for fixtures can be held in position as described for exterior lintels. The piece (C) is screwed to the side. The cleats (D) should be about 1 ft. apart. Another method of making a lintel is shown at (2), the ends of the moulds being shaped to form the set-back.

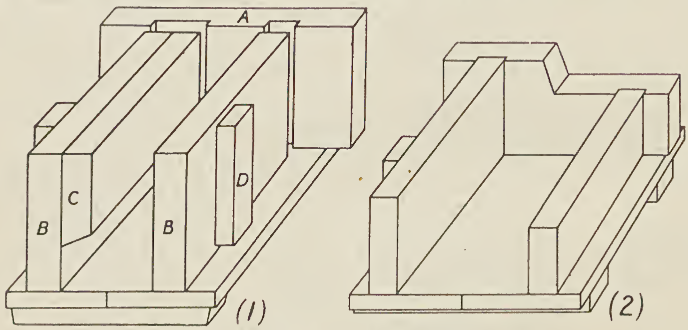


Fig. 91.—Mould for Internal Lintel.

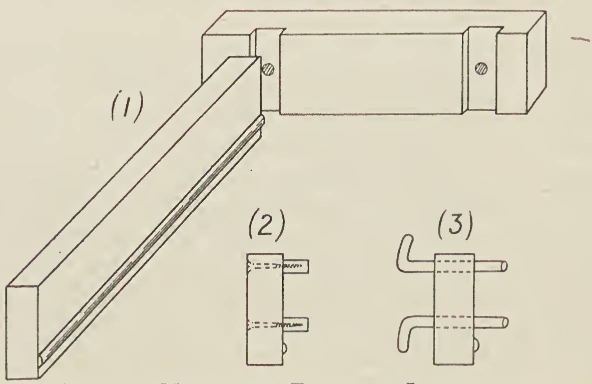


Fig. 92.—Mould for External Lintel.

A rectangular external lintel is merely a box made as shown at (1) in *Fig.* 92. The strip to form the water-drip is fixed to one side as shown. To take the fixtures, it is best to use inserts made for the purpose of fibrous material. These can be held in position by screws as shown at (2). Another method is to bore holes in the side of the mould and to pass through these pieces of round steel bar to form holes of the required depth in the concrete, into which the inserts can be placed after the mould is stripped.

FLOOR BEAM (*Fig.* 93).—Because it will be used many times, a mould for a floor beam must be very strongly made, and it should preferably be lined with sheet metal. The bottom boards should be 1⅜ in. thick screwed to 4-in. by 2-in. cleats at 1-ft. 6-in. centres. A part plan is given at (4) and a transverse section at (1). The pieces to form the splay are screwed to the sides (A), and the cleats (B) are screwed to the sides and the splay-pieces. The difference in the width of the beam at the top and bottom is provided by chamfering the bottom edges of the sides. The cores should preferably be solid. A method in

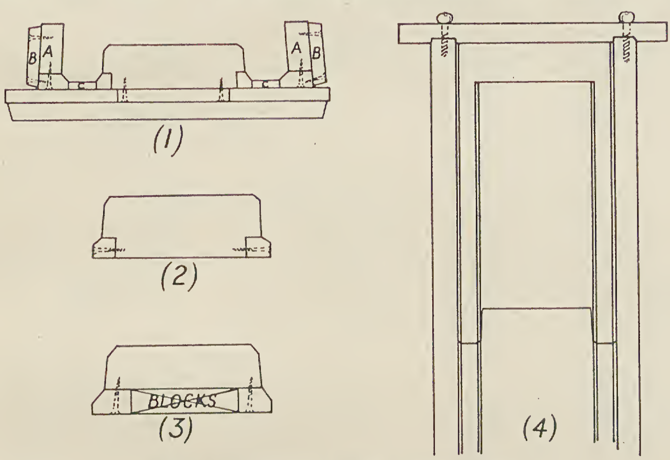


FIG. 93.—MOULD FOR FLOOR BEAM.

which the inner splay-pieces are fixed to the sides of the core is shown at (1) and (2). Timber can be saved by fixing the splay-pieces to the bottom of the core as shown at (3), with blocks at suitable intervals to keep the splay-pieces in position. The core should be at least ½ in. wider at the bottom than at the top so that it can be easily taken out. The core is screwed to the bottom, and the strips (C) placed in position. To strip the mould, a pallet is placed on top and the whole is turned over. The nuts are removed from the thumb-bolts at the corners, the bottom and core are removed, followed by the strips (C), the ends, and the sides. The precast beam to which this mould applies is shown in *Fig.* 75.

DOOR FRAME (*Figs.* 94 and 95).—At (1) in *Fig.* 94 is shown a section through a mould for making the side pieces. The bottom (2) is made of two pieces of timber (A) and (B) screwed to 3-in. by 2-in. cleats (C) about 1 ft. 3 in. apart. One side (D) is made in three pieces, the top and bottom chamfered pieces being screwed to the middle piece and the cleats (E) screwed to all three pieces. Thumb-bolts are used, as shown at (3) and (4), to fix the sides to the bottom

and to fix the ends to the sides. A template (5) should be made of the cross section of the post and used to make sure that the mould is true to shape each time it is assembled ; the position of the dowels may also be shown on the template. A dowel hole is required at each end of the post, and this is formed by passing a piece of ½-in. bar through the ends of the mould as shown at (4). Hardwood blocks are concreted into the posts for fixing hinges and latches. A method is shown at (6). The ends and sides are chamfered so that the blocks are dovetailed into the concrete, and further security is obtained by nails partly driven on the skew into the ends and inner face so that these are concreted into the post.

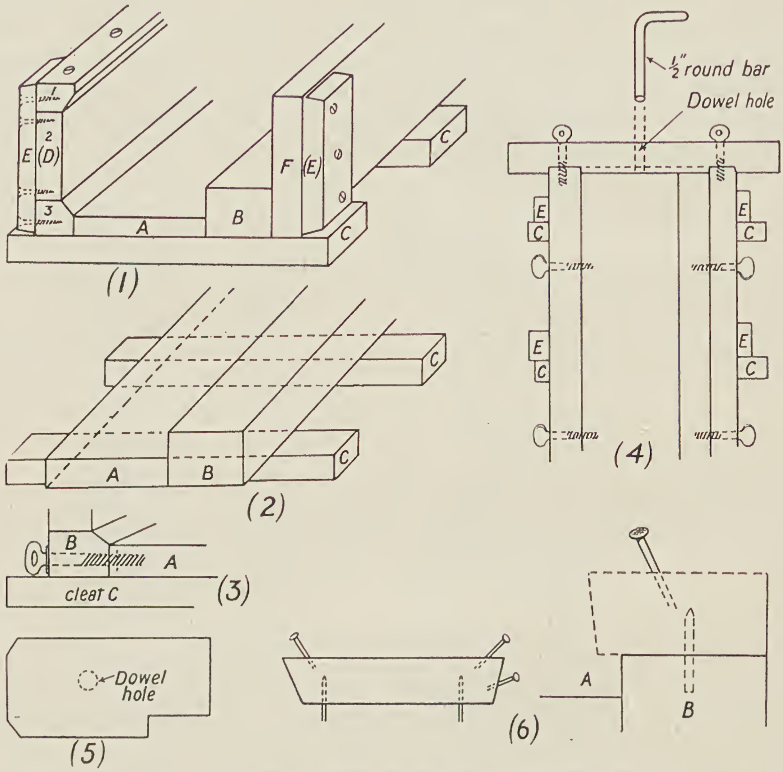


Fig. 94.—Mould for Posts of Door Frame.

The blocks rest on the liner (B), and are held in position by nails (with the heads cut off) driven into the face and fitting into holes drilled into the liner.

Some of the details of a mould for the head of the frame are shown in *Fig.* 95. The head must have a return at each end to match the jambs shown in *Fig.* 94. A part plan is shown at (1) without the side (D) shown in the section at (2). The side (D) is rebated into the bottom of the mould, or a piece of ½-in. board may be fixed to the bottom to form the rebate. The insert (B) is screwed to the bottom. The returns are formed at the ends of side (D) as shown at (3). A template should be used. The insert (B) is stopped at (Y) in drawing (1), where it is slightly chamfered to facilitate stripping of the mould ; this is repeated at both ends. The groove in the top of the head may be formed by a piece of

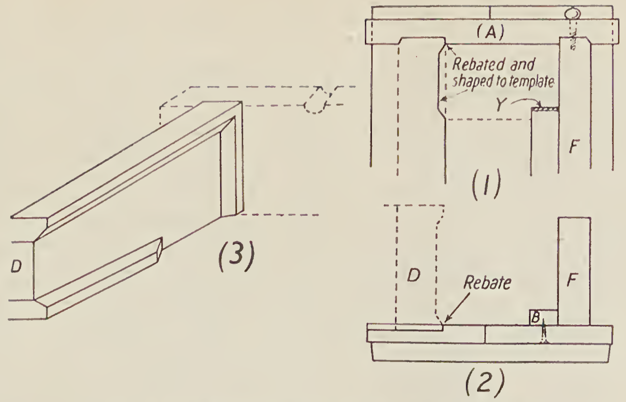


FIG. 95.—MOULD FOR TOP OF DOOR FRAME.

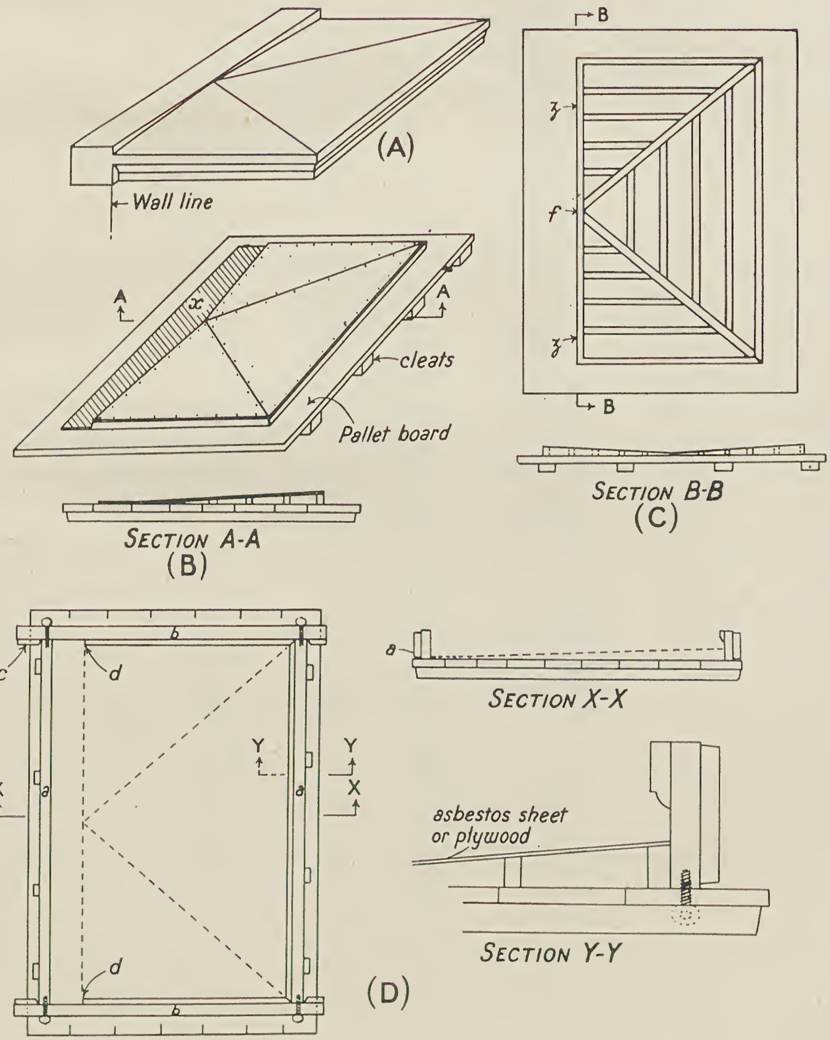


FIG. 96.—MOULD FOR DOOR HOOD.

$\frac{1}{2}$-in. round bar pressed into grooves cut in the ends. This mould is fitted with cleats and made generally as the mould for the jambs.

Door Hood (*Fig.* 96).—In this design (A) the weathering on the top slopes three ways, and stops $4\frac{1}{2}$ in. from the back, or at the wall face. A bottom board must be used as shown at (B), 6 in. longer and wider than the hood. The pad is set out and the framework built up as at (B) and (C). The thickness of the sheet of asbestos-cement or plywood must be allowed for as shown in section A—A. The framework must have the correct splay and it must be screwed to the bottom board. The framework varies in depth, but at point (f) on drawing (C) the three slopes come to a feather edge. There must be a slight draw on the timber face at (z). The sheet of asbestos-cement or plywood is screwed on in three triangles. Another sheet of asbestos-cement or plywood is then fixed as shown at (x). The mould box is shown at (D). The sides (a) are cut to the length of the hood required and attached to the ends (b) with thumb-bolts and sockets. The cleats (c) are screwed on to the face of (b) so as to provide the full width of the hood between the sides (a). Cleats must be screwed to the sides (a) where shown and at the ends. The box is placed on the bottom board as at (D) and fixed with thumb-bolts; three bolts on each side will be enough provided the hood is not longer than 6 ft. Section Y—Y shows the position of the moulding, which may be of any shape required. The moulding is fixed along the top front of the mould box, mitred, and returned at each end; it is fixed by screws passing through the side and ends of the mould box into the back of the moulding. The return mouldings are stopped on the wall line as at (d); there should be a slight draw on the moulding at this point.

Corbel (*Fig.* 97).—A design for a corbel is shown at (A) and the mould box at (B). Cleats (a) are screwed on the sides to give the required length. The ends (b) are held in position with bolts and wing-nuts. The moulding (c) is screwed to one side and one end, making a fixture of one corner of the box and helping to keep the mould square when it is assembled. The tapered piece (d) is screwed to the side and brads are used at the feathered edge.

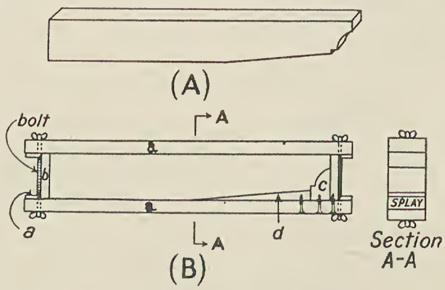


Fig. 97.—Mould for Corbel.

Eaves Gutter (*Fig.* 98).—A precast concrete eaves gutter for use with concrete block or brick walls is shown at (A). It should be made in lengths of not more than 3 ft. A section through a mould is given at (B). The middle board of the pallet is $1\frac{1}{8}$ in. thick and the side boards $1\frac{1}{2}$ in. thick. The box (C) is fixed to the bottom with two thumb-bolts at each side. The shape of the top of the gutter is formed by the pieces (c), (d), and (e). The supports (c1) and (d1) are

cut first, using one of each at each end and as many intermediate ones as are necessary according to the length of the mould ; these should be cut from 1½-in.

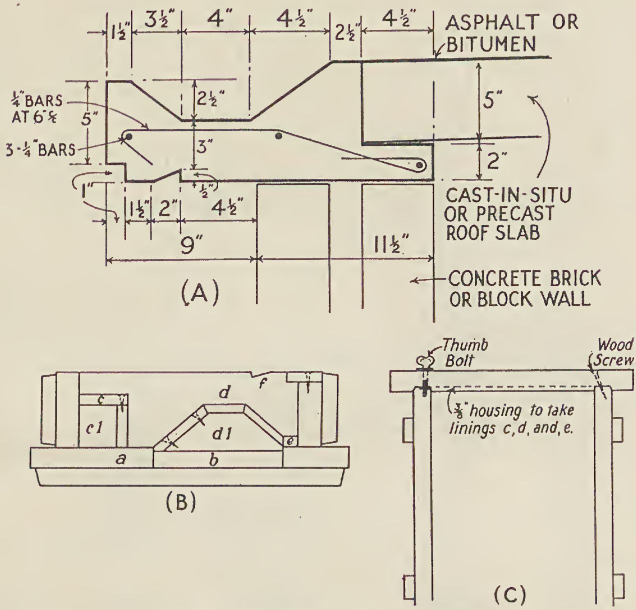


FIG. 98.—MOULD FOR EAVES GUTTER.

boards, and the boards (c) and (d) screwed to them. The drip on the underside of the gutter is formed by cutting the ends of the mould as shown at (f) in drawing (B), and using a strip of wood as a screed when the mould is filled.

COPINGS (*Figs.* 99 and 100).—The first step in making a mould for a coping as shown in *Fig.* 99 is to make a template of zinc or plywood, as shown at (3), of the desired profile. The positions of the faces of the wall and of the grooves to form the water-drips should be marked on the template. A plan of the outer mould is shown at (1), and a section with the pieces to form the slopes on the top is given at (2). The sides (A) are ½ in. deeper than the coping to allow for the thickness of the bottom boards. Cleats (D) should be screwed to the sides to prevent them twisting out of shape. The pallet should be a little larger than the overall size of the mould (4) and is fixed to the sides by thumb-screws and sockets, say, two on each side of a mould 3 ft. long. The template is used in cutting the ends, which are held in position by cleats screwed to the sides. If shorter lengths of coping are wanted, the mould is shortened by using another end resting against temporary cleats nailed to the sides as shown by dotted lines in (1). Bolts with wing-nuts are used at each end to keep the mould rigid. The timbers (B) to form the slopes on the top are finished to the template, and screwed to the pallet from the underside. When the mould is complete the template is used to make sure that it is true. The drip-grooves are formed by tapping a steel bar into the concrete (5). If desired, the copings can be made with the face at the top. In this case a mould-box is used as shown at (1) with sides as high as the side of the coping as shown at (A) in sketch (3). The template

is used to shape the ends, and the slope is obtained by a screed worked on the tops of these ends. By this method a pallet is not necessary, as the copings can be made on a level surface and left to harden. The grooves for the water-drips are formed by half-round pieces of wood which pass through the ends of the mould; these strips can be pulled out after the concrete has set but before it has hardened if a stiff concrete is used, but with a wet concrete they should

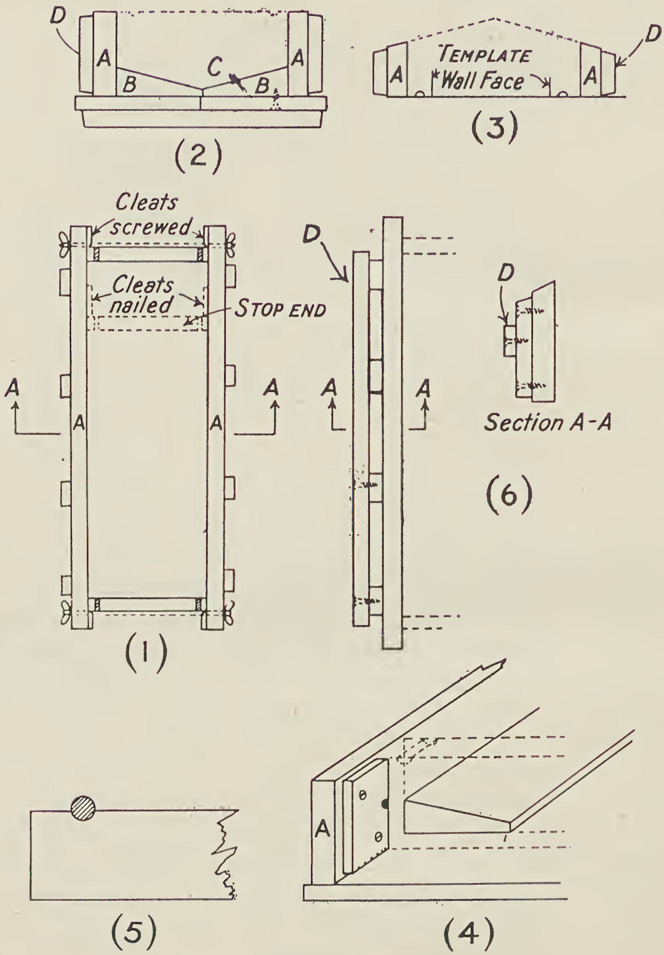


FIG. 99.—MOULD FOR COPING.

be left in position until the mould is stripped. If a mould of this type becomes bowed, this can be rectified by screwing a stretcher to the cleats on the side of the mould, as shown at (D) in drawing (6), and packing it out where necessary in order to straighten the sides.

Different methods of making another shape of coping are shown in *Fig.* 100. At (1) the top of the coping is formed against the bottom of the mould. The sides (A) are rebated to take the mouldings (B) and the sloping bottom (C). The

ends may be housed into the sides as at (B) in drawing (5), or held in position by cleats as at (C). If the ends are housed into the sides as at (B) it is important that one side of the joint be splayed as shown, so that the end will clear the casting as soon as it is loosened. If a cleat is used as at (C), one side should be bevelled for the same reason. Bolts, cramps, or thumb-bolts may be used to fix the ends to the sides and the sides and ends to the bottom. The rebates in the sides may be avoided by screwing a ½-in. board to the side as shown at (4), the board being of the correct width to form the rebate at the bottom.

At (2) is shown a mould for making the coping with the face uppermost. The mouldings are screwed to the sides (A), and the tops of the ends are cut to

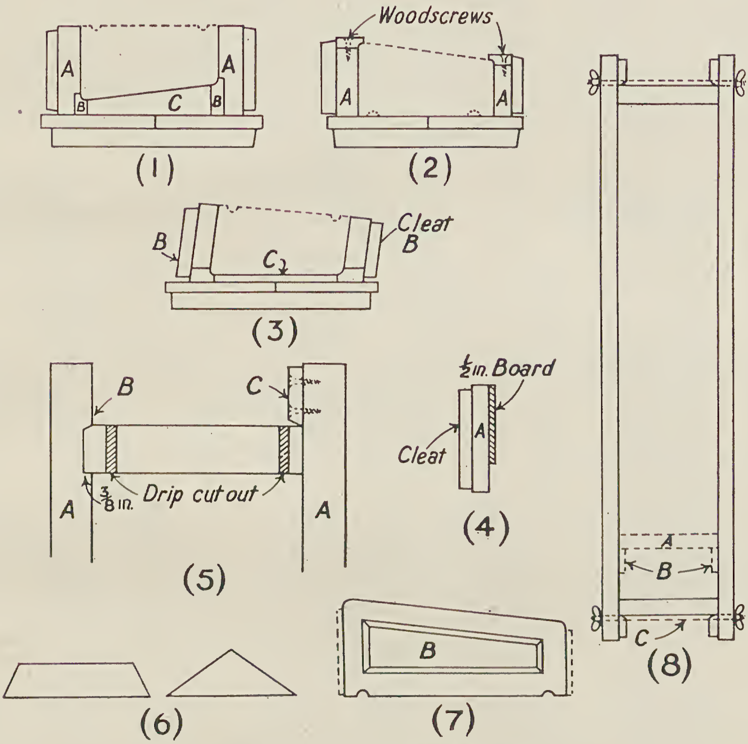


Fig. 100.—Moulds for Coping.

a slope so that the copings can be finished by a screed worked on the ends. With this type of mould a pallet board may be used or the mould can be filled on a level surface. The drip-grooves are formed by half-round strips projecting through the ends of the mould.

Another method is shown at (3), where the face is formed against the bottom of the mould and the mouldings are screwed to the bottoms of the sides. The ends are cut so that the sides have the correct slope when the mould is assembled. The cleats (B) keep the sides and mouldings in position. A ½-in. board (C) is screwed to the pallet board in order to avoid rebates to take the mouldings. The drip-grooves are formed at the top as in method (1).

Joggles are formed at both ends of each coping by means of pieces of wood,

generally of one of the shapes shown at (6), screwed to the ends as at (B) in drawing (7). At (8) is shown the use of a stop-end (A) to shorten the mould if required, so that one mould can be used for a variety of lengths. This is held in position by cleats (B) screwed or nailed to the sides ; the use of cleats is preferred to housing the false end into the sides because in the latter case the grooves would have to be filled if a longer coping were made in the same mould.

CHIMNEY CAP (*Fig.* 101).—A common type of precast concrete chimney cap is shown at (A), and is best made in sections. A mould for intermediate sections is shown at (B) and for end sections at (C). The outer mould for intermediate sections is a frame with two sides sloping so that the weathering may be formed by screeding. For the end sections, one side is rebated as shown at (a) in drawing (C), or an extra board is used, and the return weathering is formed by screwing to the ends the pieces (b) shown in drawing (D). The holes for the chimney pots are formed by cores (E), which are of the required depth and diameter and fitted with a handle. If stiff concrete is used these can be removed

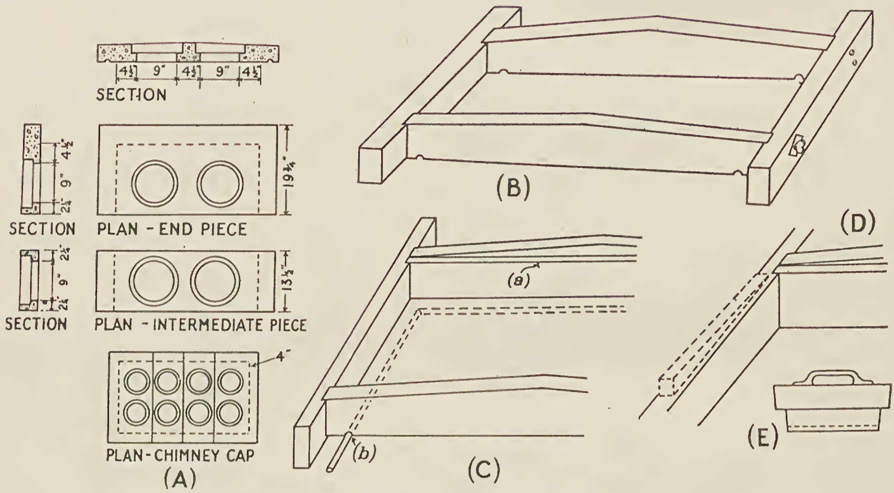


FIG. 101.—MOULD FOR CHIMNEY CAP.

as soon as the concrete has been tamped. If wet concrete is used it is better to omit the handles and to fix the cores to a batten which is in turn fixed to the ends of the mould, and to remove them when the concrete has partly set. The water-drips are formed by strips of wood placed in grooves cut in the sides of the mould as at (b) in drawing (C), and these can be pulled out as soon as the concrete is hard enough to permit this to be done. No pallets are needed if these moulds are used on a level bench or floor.

STAIRS (*Figs.* 102 and 103).—At (A) to (J) in *Fig.* 102 a mould is shown for making spandrel steps with the face uppermost to allow for a trowelled or non-slip finish. The method described may be used for either moulded or plain steps. A step is shown at (A), the dotted lines indicating the soffit and the seatings. A zinc or plywood template (B) is made and used throughout the construction of the mould. At (C) is a plan and section of the assembled mould. The moulding (c) is screwed to the front (b) and these should fit the template.

The cleats (d) are screwed to both (c) and (b). The back (e) is then made, and the splay (f) is screwed to it. The cleats (d) are screwed to pieces (e) and (f). Both sides are then cut and squared to the length of the required step plus 1 in. to allow for two ½-in. housings. The ends are made as shown at (C) and the ½-in. housing extended to take the " bird's mouth " (g) shown by dotted lines. Thumb-bolts are fitted as shown. The " bird's mouth " is made and fitted to the template, and cut to length allowing 1 in. for housing; it is then screwed in the position shown in the section with screws passing through the front of the mould. The mould is fixed to the bottom board from the sides; two ways of doing this are shown at (G), or thumb-bolts through the bottom board may

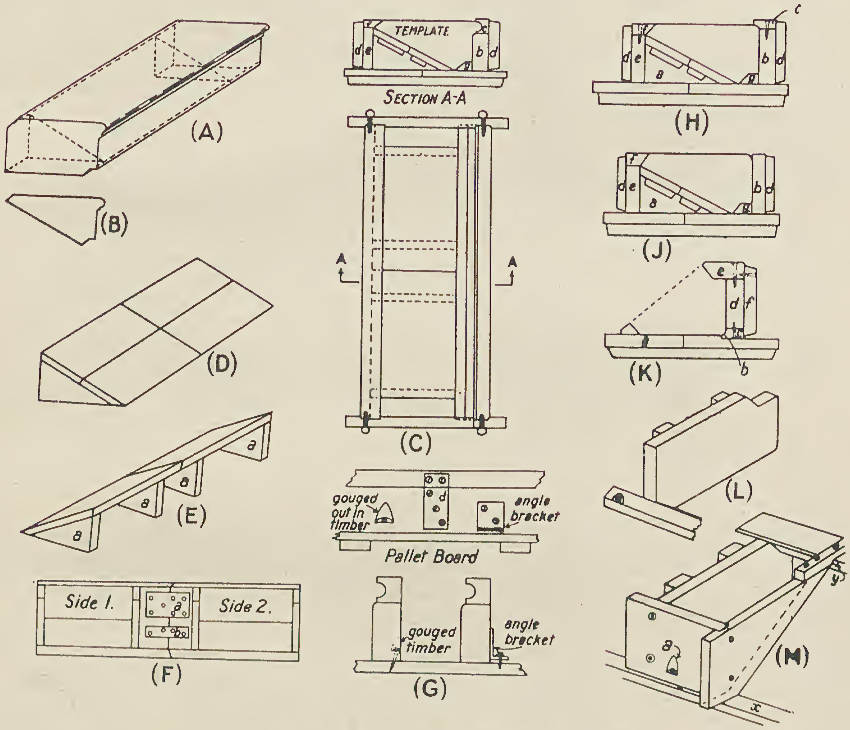


FIG. 102.—MOULD FOR SPANDREL STAIR.

be used if preferred. The soffit board is shown at (D), (E), and (F). The four pieces (a) must be accurate and the two boards are made with splays as shown at (E) and screwed to the pieces (a). The soffit board is fitted into the mould and the template used until it fits as in section A—A. The soffit is then taken out and the two pieces (a) and (b) shown at (F) are screwed into position. The soffit is now cut at an angle as at (E) and (F) but the pieces (a) and (b) are left intact. By removing the screws on side No. 1 [drawing (F)] it is possible to lift side No. 2 of the seating after casting. The soffit board is now put back into the mould and fixed by screws passing through the back of the mould into the pieces (a) seen at (E).

Variations of the mould described are shown at (H) and (J) for the pro-

duction of steps without moulding. The piece (c) in drawing (H) replaces piece (c) in section A—A, all other details being the same. In the mould shown at (J) the piece (c) is omitted and the nosing is formed with a trowel when the step is cast.

Timber is saved if the step is made with its face at the bottom of the mould as shown at (K), (L), and (M). The bottom board (a) is rebated at (b)—¼ in. to ⅜ in. deep is suitable—to take the square edge of the moulded section (c). The front of the mould is made as shown at (K). Parts (c) and (e) are screwed to (d), and cleats (f) are screwed to all three pieces.

The ends (L) are screwed or thumb-bolted to the front and a cleat is screwed on to the front to ensure that the ends are in the correct position. These ends are screwed to the bottom board as shown at (a) in drawing (M). The pieces to form the seatings are fixed to the mould after it is filled to the level of the soffit at (y), after which the seatings are filled. The mould is best filled at an angle, as shown in the drawing.

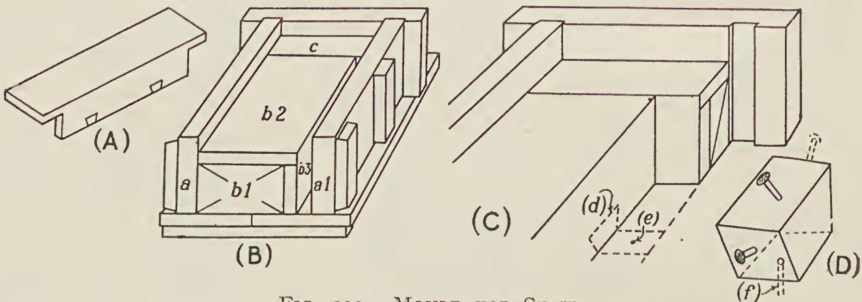


Fig. 103.—Mould for Stair.

In *Fig.* 103 a concrete tread and riser, with two wooden blocks in the bottom of the riser to take carpet fittings, is shown at (A). A wooden mould for making the step is shown at (B). The sides (a) are the length of the step plus ⅜ in. at each end for housing into the ends. Thumb-bolts are used to fix two opposite corners, and the other two corners are fixed with screws. The lining is constructed as shown. The pieces (b1) are first made, and the boards (b2) and (b3) screwed to them. Enough pieces b1 should be made for use at between 6-in. and 9-in. centres. The two end pieces (c) may be built up as shown at (C) or made solid. The mould box may be attached to the bottom board, and the lining to the side (a), with thumb-bolts, and the mould could with advantage be lined with zinc. The mould with one side removed and the position of the wooden plug (d) are shown by dotted lines in the detail at (C). The plugs should be well soaked in water before use and two or three nails should be left projecting as at (D). A dowel hole (e) is made in the bottom board and a nail tapped into the block as shown at (f), leaving ½ in. projecting and cutting the head off, to keep the plug in position while the mould is filled.

Manhole Frame and Cover (*Fig.* 104).—A mould for a manhole frame to fit a 2-ft. by 1-ft. 6-in. cover is shown. The bottom (A) in sketch (a) is at least ⅞ in. thick and is screwed to 3-in. by 2-in. runners (B). The bottom is the same width as the concrete frame plus the width of the two sides (C), and its length

is the length of the frame plus 9 in. The cleats (E) are screwed to the sides and project downwardly to cover the bottom board. The ends are housed $\frac{1}{2}$ in. or so into the sides, and splayed as at (F) to facilitate stripping. The mould may be fixed by thumb-bolts and sockets, or by bolts passing through the sides at each end. Two opposite corners of the mould are fixed by screws, so that the mould can be stripped in two pieces. The sides are fixed to the bottom by thumb-bolts passing through the bottom into sockets in the sides. Section A—A shows the shape of the wooden mouldings, and these are screwed to the bottom from the underside; if these are well bevelled so that the casting will come away easily they can be permanently fixed to the bottom and not removed each time the mould is stripped.

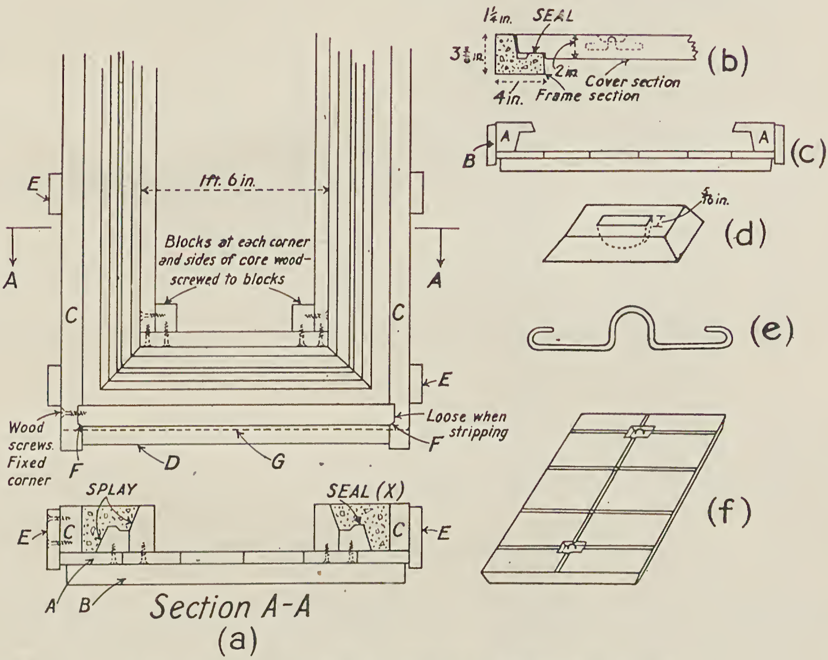


Fig. 104.—Mould for Manhole Frame and Cover.

A design for a cover is shown at (b), and the method of manufacture is shown in (c) to (e). The bottom is the width of the cover plus the width of the sides (A), and the cleats (B) keep the sides and bottom in position. A chequer pattern may be obtained by fixing chamfered or half-round metal strips on the bottom. The recesses for the lifting rings are formed by screwing two pieces of wood as at (d) to the bottom; these must be well bevelled to facilitate withdrawal, and the groove (shown in the sketch as $\frac{5}{16}$ in. to take a handle made from $\frac{1}{4}$-in. steel bar), must be $\frac{1}{16}$ in. or more larger than the size of the ring. The reinforcement may comprise a layer of mesh reinforcement $\frac{1}{2}$ in. from the bottom, or a mat may be made by wiring or welding together three $\frac{1}{4}$-in. bars in both directions. The lifting rings shown at (e) are wired to the reinforcement. A view of a cover is given at (f).

Garden Edging (*Fig.* 105).—Edging for garden paths is generally made in pieces 3 ft. long by 6 in. high by 2 in. thick, with the top edge rounded. Reinforcement is not necessary. The drawing shows a mould for making these slabs ten at a time without the use of a base. The sides, ends, and dividers should be 2 in. thick, planed smooth and true on all sides, and the ends squared. The sides (B) are rebated $1\frac{3}{8}$ in. by $\frac{1}{4}$ in. from the bottom on the inner face as shown at X, while the dividers (C) have similar rebates on both sides as shown at Z. The sides and dividers are $6\frac{3}{8}$ in. deep. The inside dimension between the ends is 3 ft. 1 in., and the sides must be of a length to project beyond the ends (F)

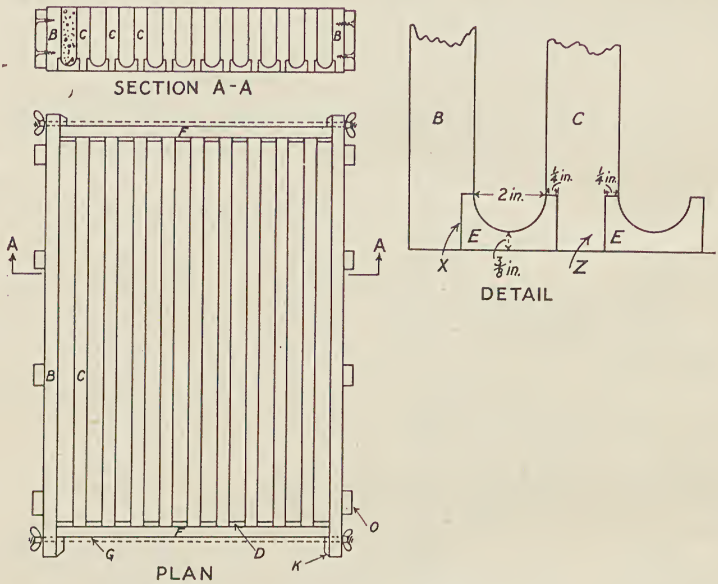


Fig. 105.—Mould for Garden Edging.

and allow for the cleats (K) which are screwed to the sides. The dividers are 3 ft. 1 in. long. The pieces (D) are cut from $\frac{1}{2}$-in. board to the shape of the cross-section of the concrete slab, that is they are 6 in. high by 2 in. wide and rounded on the bottom end ; these are screwed to the ends (F) at equal spacings according to the thickness of the dividers. The mouldings (E) are shaped to fit into the rebates in the sides as shown in the detail, and they are 3 ft. 1 in. long. Holes are drilled through the ends of the sides to take the fixing bolts (G). The mould is assembled by bolting together the sides and ends, placing the dividers between the pieces (D), followed by the mouldings. The cleats (O) are then screwed to the sides, and the mould is ready for use.

Blocks and Slabs.—Solid or hollow blocks and slabs for walls are made on hand- or power-operated machines. If the site is so far from a factory where such blocks are made that the cost of transport would make them uneconomical, and if there is a nearby source of suitable aggregate, then the builder should make the blocks himself on the site.

CHAPTER VII

SMALL GARAGES

THE garage should be made of such dimensions that it will accommodate any ordinary car, and thus a standard type of building can be designed. The general tendency is to make a garage so small that there is a difficulty in walking past the car and the execution of repairs to the car are impossible inside the garage. To provide a clearance of about 2 ft. on each side necessitates a width of 10 ft. to 12 ft., and the latter dimension is often adopted. The length depends on whether a bench is to be provided at one end. If this is required it should be about 2 ft. wide, and there should be 3 ft. for working at the end of the car, necessitating a total length of about 21 ft. inside the garage. If no bench is to be installed the length may be reduced to 18 ft. or even 16 ft. For a small car, where the cost is to be kept low, the size can be 10 ft. by 16 ft., and for a car of moderate size, with a bench, the dimensions should be 12 ft. by 21 ft.

Floor.

The floor should be constructed with 4 in. to 6 in. of plain concrete. It should be laid to fall slightly from the two side walls to the centre if a channel for drainage is to be formed. It should be level longitudinally. The concrete in the floor should be composed of 4 parts aggregate, 2 parts sand, and 1 part of Portland cement. In most cases no hardcore is necessary under this concrete, which can be laid directly on to the ground when the top spit has been removed. If a channel is formed in the middle it should be the full length of the building and discharge into an open gulley outside. The surface of the concrete should be finished with a non-absorbent material to prevent oil soaking in, as the latter is destructive to tyres; good materials for this purpose are granolithic or a mortar composed of 1 part of cement to 3 parts of sand.

When the ground is suitable it is economical to carry the concrete forming the floor to the outside of the walls as a raft upon which the walls can be built. This obviates trenches for the wall foundations. It may be considered that it is essential to carry the wall foundations down to a level below the level of atmospheric influence to avoid settlement, but the writer has constructed many buildings on the economical principle mentioned without any failure. If the ground is very poor and unreliable it will be necessary to increase the thickness of the concrete under the walls, and the bottom of the building will then be in the nature of a large slab with plain concrete beams projecting on the underside; it is advisable to lay the whole of the concrete in one process, the floor and foundations thereby forming a single member.

Walls.

There are various methods of constructing the walls in concrete, each of which has its advantages. The walls do not need to be very high, 8 ft. 6 in. or 9 ft. being sufficient, and a heavy type of construction is not essential. The concrete may be used in the form of blocks or be cast between shuttering to give a monolithic structure, or the walls may be built with light concrete columns with the intervening spaces filled with metal lath to serve as a backing for cement plaster.

In the case of block construction, conditions which have to be met in domestic buildings are not applicable to garages, and the by-laws for houses do not apply. Hollow concrete blocks will give a thickness of 9 in., and this will be satisfactory for all ordinary cases without any outside rendering or roughcast, and no plaster will be required inside. If the building is exposed to adverse weather conditions the blocks should be made with a face consisting of 2 parts of sand and 1 part of Portland cement, as this will render them impervious to rain. The remarks given in connection with block construction for the walls of houses also generally apply to garage work.

When the walls are constructed with in-situ concrete the thickness is generally 5 in. or 6 in., and a little reinforcement, say, $\frac{1}{4}$-in. bars spaced at 18-in. or 2-ft. centres, is added to prevent cracks. The vertical bars should be carried down into the concrete foundation, and into the roof when this is also of concrete, and additional horizontal bars should be provided over openings and at the corners. Although small monolithic structures have been built with some success they may not be so economical as those built with blocks, because the shuttering is expensive and a certain amount of skilled labour is necessary; it is only when shuttering can be repeatedly used that the initial outlay will be recovered. The cheapest form of construction for small buildings which are to be weatherproof and lasting is provided by concrete blocks.

Roof.

The roof may be either flat or pitched, and each type has certain advantages. The remarks given in connection with the roofs of houses deal with the merits of the two types, and the construction of flat roofs is described in Chapter V.

When a timber truss is used in a pitched roof it should be of the simple collar type, with 4-in. by 2-in. rafters spaced at 12-in. centres, and with 4-in. by 2-in. collars placed about one-third of the length of the rafters from the springing. The feet of the rafters should be spiked to a $4\frac{1}{2}$-in. by 3-in. wall-plate bedded on the inner edge of the walls. To overcome the risk of fire it is advisable to protect a timber roof on the underside. A good method is to line the soffits of the sloping and flat portions with sheets of asbestos-cement attached to the underside of the rafters and collars, using as few joints as possible. As these sheets are obtainable in 8-ft. lengths there need only be one transverse joint in a garage 16 ft. long. Another method is to cover the underside of the timber with steel mesh and apply 1 in. of plaster to form a ceiling. This will afford a certain amount of protection against fire, but it cannot be compared for fire-resistance with a flat concrete roof. The outer covering of a pitched roof may be slates, clay tiles, or concrete roofing tiles. The last are good material for this purpose as they are plentiful and when of the interlocking type form a safer

roof than any other covering as a strong wind will not lift the tiles. Asbestos-cement tiles are also suitable for the roof of a garage.

Designs for Garages.

It is possible to erect a very simple and economical garage with walls of concrete blocks and with the floor and roof of concrete. Two designs are given in *Figs.* 106 and 107.

ONE-CAR GARAGE (*Fig.* 106).—The method of construction is 9-in. hollow-block walls built off the concrete floor, which has a thickening along all four

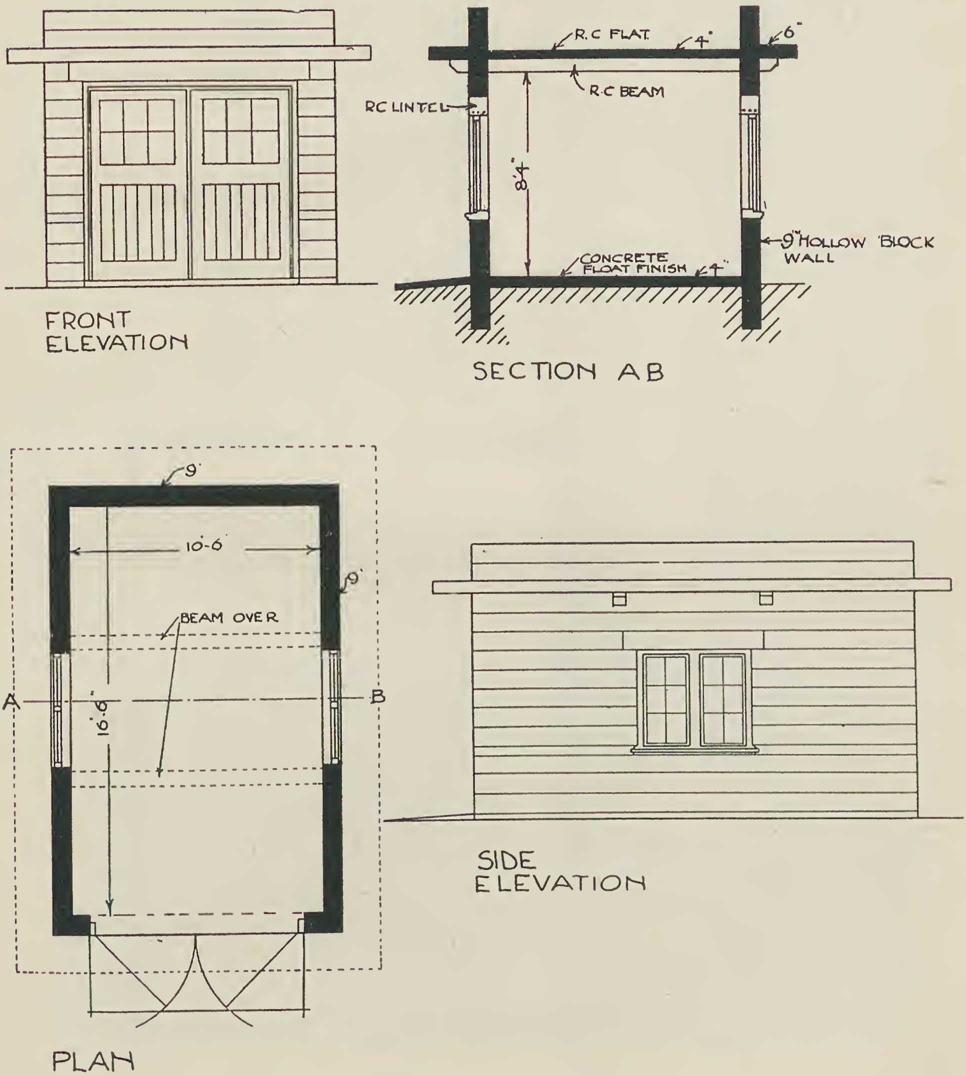


FIG. 106.—DESIGN FOR ONE-CAR GARAGE.

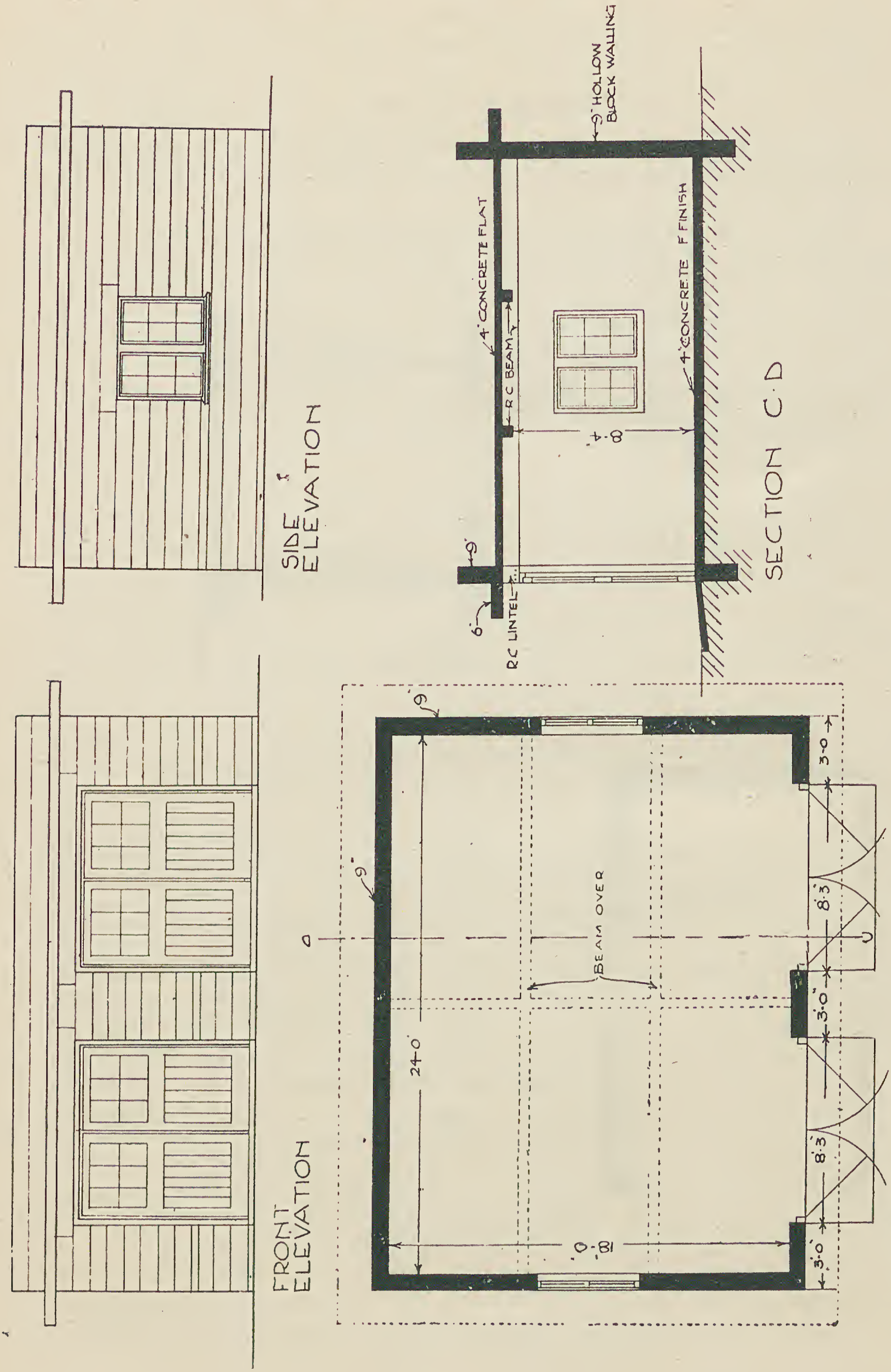


FIG. 107.—DESIGN FOR TWO-CAR GARAGE.

edges forming a raft like an inverted box. The depth at the edges will depend on the nature of the soil, but a depth of 2 ft. below the level of the floor will be ample in most cases. The walls need not be plastered on the inside, and the external face of the blocks should be made of suitable material and texture to avoid the need for roughcast or rendering. The roof can be constructed with light precast reinforced concrete slabs carried on the external walls or two small intermediate beams, which can also be precast. The roof slab is projected beyond the face of the wall to cast a shadow, and no ornament has been added. Lighting is arranged on two sides, and the windows are low to throw the light at a convenient level to enable repairs or adjustments to be made to the car.

Two-Car Garage (*Fig.* 107).—Owing to the larger span of this design for a two-car garage a central beam is provided for the roof, but in the event of the garage being divided by a permanent partition in the centre at the time of construction the beam could be omitted and the cross-beams could bear on the partition. With the floor space shown, however, it would be possible to accommodate motor-cycles with side-cars in addition to two cars, and three small cars could be accommodated at one time. As the methods of construction with concrete generally are described in previous chapters, it is not necessary to deal with the details here.

Bills of Quantities.—The quantities of materials required, including the number of blocks, are given in the tables of quantities in Appendix II.

Portable Concrete Garages.

The garages illustrated in *Fig.* 108, with the exception of the concrete floor which is cast on the ground, are constructed of precast slabs, pilasters, sills, plates, collar beams, rafters, and other necessary pieces. The pieces are of such a size that two men can easily lift and handle the largest. In building the garage the

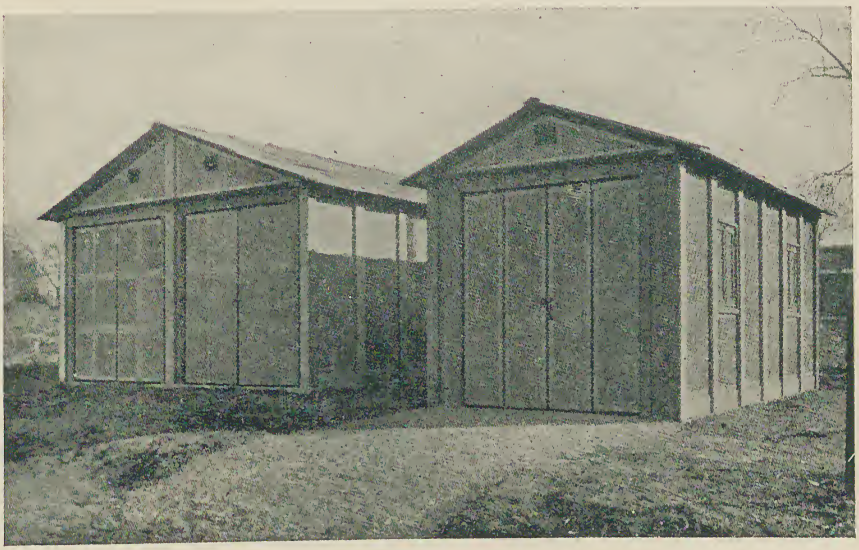


Fig. 108.—Portable Concrete Garages.

concrete floor is placed first. After this has hardened a pilaster 8 ft. high is erected at the corner and a section of concrete sill placed. Then one of the slabs, 33 in. wide, 8 ft. long, and 1 in. thick, is put into place. The pilasters and sills are slotted so that the edges of the slabs fit into them. Next, an intermediate pilaster, slotted on two sides, is erected, another section of sill is laid, and the second slab placed. This operation is continued until the wall is completed. Pre-cast plates similar to the sills are then fitted on the top of the wall. To prevent spreading, opposite sides of the wall are tied together with precast collar beams. These beams are bolted at the ends to the pilasters by means of bolts embedded in the pilasters at the time of manufacture. The roof, which is of slab construction, is supported by precast concrete rafters 3 ft. apart. The lower ends of the rafters rest on the pilasters and are bolted to them with the same bolt that passes through the collar beams.

The doors consist of concrete slabs cast in steel frames provided with hinges so that the various sections will fold together. Bolts for the attachment of hinges are embedded in the concrete corner piers at the time of their manufacture. Window sashes are also made of concrete. Short slabs are used for the wall above and below the windows ; these are slotted on the ends next to the window so as to give a tight joint. The sides of the sash fit into the slots in the pilasters. No mortar is used in the construction of the garage, and if required the building can be taken apart readily and the pieces transported to a new site and rebuilt. The concrete pieces for such a building would be manufactured in bulk and made in sections for erection on the site. In addition to their use as garages, for which they are primarily intended, this type of building is useful for a variety of purposes for which a cheap, portable, durable, and fire-resisting structure is required.

CHAPTER VIII

SURFACE FINISH

THE surface treatments now in use for concrete walls may be divided into two classes, namely, those in which the colour and texture are obtained by treatment of the surface of the concrete, such as by revealing the aggregate of which the concrete is made; and those that involve the application of another material such as white or coloured rendering, rough-cast, paint, or cement wash.

Exposed Aggregate and Stone Finishes.

If a cheap supply of local stone is available, concrete may be made to match the same shade or texture at little extra expense, particularly if precast blocks are used. The method is to use the natural stone as the aggregate for a facing of, say, $\frac{3}{4}$ in. to 1 in., the aggregate in the remainder of the block or slab being gravel or other material. The stone must be crushed to a suitable size, depending on its texture; that is, the finer the grain of the stone the smaller it must be crushed if the concrete is to match the original. The maximum size will generally be about $\frac{1}{8}$ in. In order that the colour of the cement shall match the colour of the stone it is necessary to add a pigment to the cement or to use white or coloured cement in which the pigment has been incorporated by the manufacturer. The cement may be coloured by the addition of metallic oxides, but these weaken the concrete, and should not be used in proportions exceeding 15 per cent. of the volume of the cement; a smaller proportion, say, 10 per cent., is desirable, and it will often be found that a desired shade can be obtained by the use of smaller proportions of pigments which are darker than the colour required in the stone. The cement and pigment must be thoroughly mixed if the resulting colour is to be uniform. The following are the colours produced by different pigments: Buff and yellow—yellow oxide or barium chromate; Grey and slate—manganese black; Brown—burnt umber or brown oxide of iron; Blue—ultramarine blue; Green—green oxide of chromium or greenish-blue ultramarine (green also results from a mixture of yellow ochre and ultramarine blue); Pink or red—red oxide of iron, or crimson lake with alumina base; Chocolate—manganese black, black oxide of iron or copper, and red oxide of iron, mixed together; Black—manganese black.

Due to the small size of the aggregate a fairly rich mixture must be used for the facing, say, 1 : 3. This special concrete may be placed in the bottom or the top of the mould and the mould filled with a cheaper 1 : 2 : 4 gravel concrete. When the concrete has hardened, the faces which have been formed against the mould will be smooth, and they may have small holes in them due to the presence of trapped air or water. The method of treating these surfaces so as to produce

a texture similar to that of the stone used as aggregate depends upon the nature of the stone.

If a coarse texture is desired (for example, granite), the concrete block or slab should be made with the face at the top, and as soon as possible after casting the face scrubbed with a stiff brush and water to remove the film of cement and reveal the aggregate. This should be done before the cement has set too hard to permit brushing off, but if it is impossible to carry out the scrubbing until the cement is so hard that scrubbing with clean water is ineffective, a solution of 1 part muriatic acid to 6 parts water may be used. The solution should be washed from the concrete as soon as the desired penetration has been obtained, and it should not be allowed to come into contact with the hands.

For matching fine-grained stones or dressed stone, mason's tools or carborundum stones or discs may be used to remove the surface when the concrete is hard. This process is more expensive than scrubbing, but gives excellent results if it is desired to match dressed natural stone exactly.

Attractive results may be obtained by removing the surface cement by scrubbing when ordinary aggregates, such as shingle, are used throughout the concrete ; the object is to show the stones instead of a cement film on the face of the concrete. Similar results are obtained by using white or coloured sands with white or coloured cements. Many sands when made into concrete and scrubbed closely resemble some natural stones ; for example, white sand and white cement resemble Portland stone, buff coloured sand and cement resemble Bath stone, and so on. Exposure of the aggregate is a suitable method for the treatment of cast-in-situ concrete walls. When depositing the concrete it is pressed against the face of the shuttering so that an even distribution of aggregate is obtained on the exposed face. If a special facing is required this is generally obtained by making the outer 2 in. or so of the wall with aggregate of the desired colour and size and with a white or coloured cement. The remaining part of the wall is made in ordinary concrete. The two concretes are placed simultaneously but are separated by a thin metal plate, which is raised as concreting proceeds.

Instead of exposing the aggregate by scrubbing, tooling is also used. This process, called bush-hammering, fractures the pieces of aggregate, and reveals the interior of the stones, resulting in attractive surfaces if gravel of many coloured stones is used.

Applied Finishes.

Concrete walls can be roughcast, pebble-dashed, or rendered in the same way as brick walls, with the added advantage that, due to the concrete being less absorbent, there is less risk of the rendering peeling off. No description is necessary here of the well-known methods of roughcasting or pebble-dashing walls, except to point out that in the case of in-situ concrete it may be necessary to hack the surface in order to provide a key for the rendering.

Among other finishes are coloured cement renderings in a variety of colours and textures. The first essential is to provide a key to allow the rendering to adhere to the face of the concrete and also to provide a support whilst the mortar is plastic. The surface may be scrubbed with a wire brush or hacked if necessary upon removal of the shuttering, the depressions between the pieces of the exposed

aggregate providing the necessary key for the rendering. Other methods include hacking the surface of the concrete or applying a spatterdash coat. The key formed by these methods must be regularly distributed over the whole surface and the indentations should not exceed $\frac{1}{8}$ in. in depth. A spatterdash coat consists of a mixture of 1 part of Portland cement to $1\frac{1}{2}$ parts of coarse sand and 1 part of water (by volume). The surface of the wall should be thoroughly cleaned and wetted before applying the spatterdash coat, and the mixture is thrown on to the surface to present an uneven roughcast appearance and should be allowed to dry out for 30 hours. Having provided an efficient key the surface to be rendered must be cleansed from all dust and loose material and be well wetted before the first coat, or backing, of rendering is applied.

The materials employed for rendering are (1) sand, crushed or broken stone, marble, granite, or other suitable materials; (2) Portland cement; (3) hydrated lime; (4) hair; and (5) water.

The aggregate must be fairly coarse, clean, and well graded. In most renderings two types of aggregates are used—that for the first, or backing, coat or coats and that for the finishing coat. The aggregate for the backing coat will not materially affect the texture of the finish; coarse sand is generally employed, but other aggregate is permissible provided it passes a $\frac{1}{4}$-in. sieve.

For the finishing coat a good silica sand is the most suitable, but it must be free from extraneous substances, although a certain amount of colouring matter, such as is found in gravel sand, can be allowed if it is in accord with the colour required. For light shades white silica sand is best, while special white aggregates are available and are suitable where pure white or definite colours are required. If crushed stone is used, crushed limestone is recommended, and it should be crushed to pass a $\frac{1}{8}$-in. sieve. If it is required to add sand it is necessary to reduce the very fine material by a quantity equal to the volume of the sand added. As the colour of the cement permeates the whole of the mixture a white or coloured cement should be used for the finishing coat. Hydrated lime makes the mortar easier to work and reduces the amount of water necessary, which is a desirable feature as it is advisable to restrict the amount of water in mixing renderings. If the addition of hair is necessary it should be as long as possible and should be well beaten and cleansed from dust and impurities. Long goat hair is probably the best.

In dealing with large areas of one colour it is best to mix in a dry state coloured cement and aggregate sufficient for the whole of the work at one time and store it in sacks or other containers. The surface must be prepared to receive the final coat of rendering. Evenly distributed and wavy horizontal combings to provide the key are preferable and if one or more backing coats are to be given the combing should be carried out on all coats; the indentations should not be more than $\frac{1}{8}$ in. deep and about $\frac{1}{8}$ in. to $\frac{1}{4}$ in. apart.

The surface to be rendered should be thoroughly wetted and allowed to dry until the hand is only just damp after drawing it over the surface. Each coat of rendering should be treated in the same way, and allowed to stand until the amount of absorption, or suction as it is generally known, is sufficient for the succeeding coat to be placed.

The composition of the finishing coat will vary in accordance with the colour, texture, and design required and the size of the aggregate. The proportions

generally should be 3 parts of aggregate to 1 part of cement. If the aggregate is fine a richer mixture is necessary; also, if it is required to produce a more intense white or other colour, it is necessary to use additional cement so that a mixture of $2\frac{1}{2}$ parts of aggregate to 1 part of white or coloured cement is allowable in these circumstances; a richer mixture is not recommended as an excess of cement would come to the surface and be liable to craze and crack. The thickness of the finishing coat should not be less than $\frac{1}{8}$ in. and not more than $\frac{1}{4}$ in.

Care must be taken when using a steel trowel. A wooden float is advised where possible. A steel trowel has a tendency to stain white cement surfaces; when a finish is required necessitating the use of a steel trowel its application should be rapid and over-trowelling should be avoided. A steel trowel is necessary when a hard and fine surface is required, whilst when a "floated surface" is required (that is, when more sand than cement is to show on the face) a wooden float is more suitable. To roughen the surface to a greater extent the float may be covered with sacking, carpet, cord, or similar materials. Celulloid trowels are available to prevent staining white cement.

To obtain a smooth surface of one colour the mixture should be applied in the ordinary manner, but if more than one colour is to show it is usual to apply the colours in their various positions and trowel the whole together. When one colour is to predominate throughout, the whole of the surface is first covered to a thickness of $\frac{1}{8}$ in. with a mortar of the predominating colour, after which mortars of the other colours are placed in position and the whole trowelled together.

The rendering must be protected from frost, hot sun, drying winds, and heavy rain. It must be kept damp by spraying, or preferably damp cloths or hessian should be hung in front.

Although the use of ready-mixed coloured cements is recommended, in some cases it may be desirable to mix mineral pigments with the cement on the site. Particulars of suitable pigments have already been given. To obtain even colouring the mixing must be very thorough, the procedure being to trowel or spade the cement and colour together and then to pass them twice through a sieve with 40 meshes to the square inch. No greater proportion than 15 per cent. of pigment should be added, since, although the question of strength does not materially enter into the question of rendering, the waterproofing properties of the rendering are affected by the addition of an excessive quantity of non-cementitious fillers.

Among other methods of treating concrete surfaces is that by which coloured or white cements are sprayed under pressure on to the surface to be treated. By this method large areas of wall or ceiling may be quickly covered with a coloured cement coating. Various effects may be obtained by the use of different coloured cements, and textural effects are obtainable by first treating the surface of the wall as described for renderings.

Ordinary oil paints are not suitable for use on concrete as their colour is affected by the free lime in the concrete and also by efflorescence. One of the special cement paints, which are durable, which do not flake off, and which retain their colour if they are kept clean should be used. These cement paints are also waterproof.

Coloured Concrete Blocks.

For some houses at Liverpool, machine-made coloured concrete blocks were used, the external markings differing in every case. The aggregate for blocks which are not exposed externally is clinker in the proportions of 5 parts of clinker to 1 part of Portland cement. Blocks which are exposed externally differ from the internal blocks only in having a facing about 1 in. thick of concrete composed of 3 parts of aggregate to 1 part of cement, the two mixtures being cast together in one operation. The aggregate in the facing may be sand only, or gravel, crushed granite, or other suitable stone, and with it pigment is incorporated. Variety in surface texture is obtained by stippling the blocks with the same mixture as the 1-in. facing material, except that the aggregate is a little smaller in size. The walls and partitions throughout are of concrete slabs, 2 in., 3 in., or 4 in. thick according to the position they occupy and the load to be carried. External walls are 9 in. thick formed of two leaves, the outer leaf of 4-in. faced slabs and the inner leaf of 3-in. slabs with a 2-in. cavity between ; the two leaves are linked together at intervals with tarred or galvanized-iron ties. Party walls are 8 in. thick, with two 3-in. leaves and a 2-in. cavity, and are also tied together. Partition walls which are two stories high, or which though only one story high carry floor joists, are of 4-in. slabs, and single-story partitions which do not carry floors are of 2-in. slabs. The walls are in various shades of buff, grey, white, and red, with stringcourses and cornices in black and other shades. Quoins of a different tone are introduced in the external angles, under bay windows, and at the sides of doors. In order to eliminate plastering, sand-faced concrete blocks, 18 in. by 9 in., were used for interior walls set with a flush mortar joint and a few days afterwards gently rubbed with soft stone. Ordinary wall-paper is applied to the blocks, the only precaution necessary being to add a little size to the paste, a coat of which is given to the wall as well as to the paper.

APPENDIX I

Abstract of the Report of the Committee appointed by the Government to Inspect Concrete Houses built between the Years 1919 and 1944 (" Post-war Building Studies No. 1, House Construction," H.M. Stationery Office. Price 2s.).

Among the houses inspected and discussed in the report were about a thousand built with in-situ walls poured between permanent shuttering of asbestos-cement sheets. The walls were $6\frac{3}{4}$ in. thick and the asbestos-cement sheets $\frac{3}{16}$ in. thick ; in some cases clinker concrete was used and in others a 1 : 3 : 3 mixture of cement, clinker, and gravel. It is stated that the maintenance cost of these houses was high, chiefly due to the penetration of rain through the walls as a result of the cracking of the asbestos-cement sheets.

More than 2,000 houses were built with walls composed of two leaves of clinker-concrete slabs, each $2\frac{1}{2}$ in. thick, used as shuttering for a 4-in. thickness of 1 : 6 ballast concrete ; the outside was rendered and the inside plastered. These houses are satisfactory.

About six thousand houses were built with in-situ cavity walls, comprising two leaves of clinker concrete 3 in. or $3\frac{1}{2}$ in. thick separated by a 2-in. or 3-in. cavity, or an inner leaf of clinker concrete and an outer leaf of gravel concrete, with roughcast on the outside. Except in some cases where unsound clinker was used, and some unimportant cracks at window openings, these have given satisfactory service.

Various arrangements of precast concrete posts with an infilling of concrete slabs to form cavity walls (pier-and-panel systems) were used for more than 16,000 houses. Except in cases where unsound clinker was used, these houses were satisfactory.

Walls built of concrete slabs from 3 in. to $4\frac{1}{2}$ in. thick separated by a cavity were used for about 1600 houses ; in some cases clinker concrete was used and the outside rendered, while in others gravel concrete was used and rendering dispensed with. Between 1923 and 1927 nearly eight hundred houses were built with " no fines " concrete walls. Between 1939 and 1944 a further thousand houses of this type were built in Scotland for the Scottish Special Housing Association. The walls are 9 in. thick and a special type of shuttering was used. These houses are satisfactory except that additional thermal insulation is considered to be desirable.

The committee found that, with a few exceptions, the concrete houses inspected were of adequate strength, that the insulation was good, that the tenants were of opinion that the houses were comfortable to live in, and that the cost of maintenance was no greater than for brickwork. Except for the walls, the materials and methods of construction were conventional.

So far as cost is concerned the Committee states that there seems to have been little difference between concrete and brick. No-fines construction is said to be a little cheaper than 11-in. cavity brickwork when it is unrendered, and a little dearer when the outside is rendered. In-situ concrete poured between permanent shuttering of asbestos-cement sheets was slightly cheaper than brickwork, but the cost of maintenance was higher, due to the penetration of moisture through cracks in the sheeting. Walls built with a core of in-situ concrete between permanent shuttering of breeze slabs cost about 5 per cent. more than comparable brickwork, and maintenance costs were about the same. Cavity walls built in situ cost about the same as brickwork, and maintenance costs were about the same except in cases where unsound clinker

was used. There seems to be no reliable evidence of the cost of pier-and-panel construction, but it is not considered that it was cheaper than brickwork, while the cost of maintenance was not excessive. The initial cost and the cost of maintenance of hollow walls built with concrete blocks was about the same as brickwork.

The question of speed of erection was also investigated by the Committee, and the conclusion was reached that none of the systems described had any considerable advantage compared with brick construction ; for example, the report states that no-fines walls were built " at least as quickly as brick walls " ; there are no accurate records to bear out statements that in-situ concrete cavity walls were built quicker than brickwork ; in the case of pier-and-panel houses, it is stated that " it seems likely that with good organization an increase in speed can be expected compared with brick construction " ; while in the case of concrete block walls it is stated that there did not appear to be any considerable increase in the cost of building.

The thermal insulation of the concrete walls considered by the Committee was compared with 11-in. cavity brickwork. Generally it was found that there was little difference. The poorest results were given by the 8-in. no-fines concrete walls.

APPENDIX II

Quantities of Materials required for Designs

Descriptions	Types							Remarks
						Garages		
	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6 One car	No. 7 Two cars	
Dig for trenches, part return, fill and ram, and cart away remainder	16 cu. yd.	19 cu. yd.	21 cu. yd.	23 cu. yd.	18 cu. yd.	3 cu. yd.	5 cu. yd.	No allowance for levelling.
Concrete (1 : 2 : 6) in foundations . .	$7\frac{1}{2}$ cu. yd.	$8\frac{1}{2}$ cu. yd.	11 cu. yd.	11 cu. yd.	8 cu. yd.	3 cu. yd.	5 cu. yd.	See section for size.
Concrete Walls, etc.								
2″ Slabs in partitions, bedded and jointed in cement mortar (18″ × 9″ × 2″ blocks)	25 sq. yd. (200 blocks)	67 sq. yd. (536 blocks)	11 sq. yd. (88 blocks)	—	—	—	—	No. of blocks as equivalent no. of whole blocks.
$4\frac{1}{2}$″ do. (18″ × 9″ × $4\frac{1}{2}$″ blocks) . . .	124 sq. yd. (992 blocks)	126 sq. yd. (1007 blocks)	265 sq. yd. (2120 blocks)	136 sq. yd. (1088 blocks)	86 sq. yd. (688 blocks)	—	—	Do.
9″ Hollow-block walls, bedded and jointed (18″ × 9″ × 9″ blocks)	68 sq. yd. (540 blocks and 10 half blocks)	77 sq. yd. (609 blocks and 17 $\frac{1}{2}$ do.)	72 sq. yd. (565 blocks and 23 $\frac{1}{2}$ do.)	65 sq. yd. (486 blocks and 67 $\frac{1}{2}$ do.)	42 sq. yd. (311 blocks and 50 $\frac{1}{2}$ do.)	53 sq. yd.	81 sq. yd.	See plans for positions.
Hollow walls in two $4\frac{1}{2}$″ thicknesses with 2″ cavity, bonded with galvanized wrought-iron ties (two to every yard)—external leaf to be dense blocks suitable for facing; internal blocks to be of porous concrete Block sizes:—Whole, 18″ × 9″ × $4\frac{1}{2}$″ Three-quarter, $13\frac{1}{2}$″ × 9″ × $4\frac{1}{2}$″ Half, 9″ × 9″ × $4\frac{1}{2}$″	203 sq. yd. (2581 blocks, 190 $\frac{3}{4}$ do. 626 $\frac{1}{2}$ do. 184 corner do.)	222 sq. yd. (2676 blocks, 512 $\frac{3}{4}$ do. 524 $\frac{1}{2}$ do. 184 corner do.)	254 sq. yd. (3186 blocks, 436 $\frac{3}{4}$ do. 642 $\frac{1}{2}$ do. 184 corner do.)	135 sq. yd. (1708 blocks, 328 $\frac{3}{4}$ do. 151 $\frac{1}{2}$ do. 104 corner do.)	131 sq. yd. (1893 blocks, 216 $\frac{3}{4}$ do. 186 $\frac{1}{2}$ do. 118 corner do.)	—	—	—
18″ × 9″ × $4\frac{1}{2}$″ slabs under walls . .	113 ft. (151 blocks)	130 ft. (173 blocks)	154 ft. (205 blocks)	146 ft. (195 blocks)	125 ft. (167 blocks)	—	—	—
Dampcourse: two courses slates in cement mortar	143 sq. ft.	181 sq. ft.	198 sq. ft.	196 sq. ft.	145 sq. ft.	—	—	—

Extra over walls forming one course in coloured band (blocks 18″ × 9″ × 4½″)	122 ft. (81 blocks)	130 ft. (87 blocks)	154 ft. (103 blocks)	—	—	—	—	See notes on coloured concrete.
Do. forming 4″ × 3½″ backing to window sills in blocks with rounded top edge	69 ft.	92 ft.	120 ft.	53 ft.	35 ft.	10 ft.	10 ft.	See details.
2″ × 9″ lintels, average 2′ 4″ long, reinforced with two ½″ steel bars	4	10	—	—	1	—	—	—
4½″ × 9″ do., 3′ 3″ long, and do.	—	6	8	5	3	—	—	—
4½″ × 9″ do., 4′ long, and do.	12	6	12	8	6	—	—	—
9″ × 9″ do., 3′ 4″ long, and do.	—	—	—	5	—	—	—	See notes on lintels, Part IV.
9″ × 9″ do., 4′ 6″ long, and do.	—	—	—	—	1	—	—	
9″ × 9″ do., 5′ 7″ long, with three ½″ bars	—	—	—	—	—	2	2	—
9″ × 9″ do., 9′ 6″ long, and do.	—	—	—	—	—	1	2	—
11″ × 9″ do., 3′ 4″ long, with two ½″ bars	10	10	8	3	5	—	—	—
11″ × 9″ do., 4′ long, and do.	2	2	8	2	2	—	—	—
11″ × 9″ do., 4′ 6″ long, and do.	2	4	—	—	—	—	—	—
11″ × 9″ do., 5′ 7″ long, with three ½″ bars	2	12	4	1	2	—	—	—
11″ × 9″ do., 7′ 11″ long, and do.	4	2	4	4	2	—	—	—
11″ × 9″ do., 8′ 10″ long, and do.	2	—	—	1	—	—	—	—
11″ × 9″ do., 10′ 2″ long, and do.	—	—	4	—	—	—	—	—
9½″ × 4″ rebated, moulded, weathered, and throated window sills, with $\frac{7}{32}$″ bars and ⅛″ links at 6″ centres	81 ft. (18 sills)	104 ft. (24 sills)	132′ 6″ (22 sills)	63 ft. (15 sills)	39 ft. (9 sills)	10′ 6″ (2 sills)	10′ 6″ (2 sills)	See detail.
Square-seated ends	36	48	44	30	18	4	4	—
Mitres to suit bay window	—	—	8	—	4	—	—	—
4″ × 2½″ rebated and chamfered window frames, reinforced with $\frac{7}{32}$″ bars and ⅛″ links at 6″ centres	221 ft. (18 frames)	294 ft. (24 frames)	295 ft. (22 frames)	187 ft. (15 frames)	114′ 5″ run (9 frames)	28′ run (2 frames)	28′ run (2 frames)	See detail.
5″ × 4″ double rebated and chamfered mullions, and do.	51 ft. (12 mullions)	55 ft. 6 in. (14 mullions)	106 ft. (26 mullions)	42 ft. (9 mullions)	18 ft. 6 in. (4 mullions)	9 ft. 6 in. (2 mullions)	9 ft. 6 in. (2 mullions)	See detail.
5″ × 5″ do., angle mullion	—	—	18′ 6″ (4 mullions)	—	9′ 2″ (2 mullions)	—	—	—
5″ × 3″ rebated and chamfered door frames, reinforced with three $\frac{7}{32}$″ bars and ⅛″ links at 6″ centres	103 ft. (6 frames)	132 ft. (8 frames)	137 ft. (8 frames)	67 ft. (4 frames)	67 ft. (4 frames)	—	—	See detail.
7″ × 3″ do.	—	—	—	—	—	23 ft. 6 in. (1 frame)	47 ft. (2 frames)	—
11″ × 9″ door steps, rounded on one edge	21 ft. (6 steps)	21 ft. (6 steps)	25 ft. 6 in. (8 steps)	22 ft. 6 in. (4 steps)	7 ft. (2 steps)	—	—	—
Bed and point window frames	18	24	22	15	9	2	2	—
Do. door frames	6	8	8	4	4	1	2	—
9″ × 9″ × ¼″ concrete tiles to form skirting cove at junction of wall and floor	436 ft.	495 ft. 2 in.	627 ft.	278 ft.	212 ft.	—	—	—
Form 9″ × 9″ outlets in parapets	2	2	3	3	3	1	2	—
Form holes in 6″ overhanging cornice for 3″ downpipe	2	2	3	3	3	1	2	—

Note.—The quantities for Types Nos. 1, 2 and 3 are for one pair of semi-detached houses.

Quantities of Materials required for Designs—*continued*

Descriptions.	Types							Remarks
	No. 1	No. 2	No. 3	No. 4	No. 5	Garages: No. 6 One car	Garages: No. 7 Two cars	
Small Blocks								
Block = 9″ × 4½″ × 3″								
9″ reduced work	29 sq. yd.	51 sq. yd.	76 sq. yd.	32 sq. yd.	31 sq. yd.	—	—	See block bonding plans.
4″ × 9″ lintels, 2′ 9″ long, with two ½″ bars	2	6	8	3	2	—	—	Fireplace openings.
6″ × 9″ do., 3′ 9″ long and do.	2	2	2	1	1	—	—	—
4½″ × 5″ × 4½″ blocks, 1″ projection, to form chimney caps	2	12	12	4	8	—	—	—
9″ × 5″ × 4½″ do., and do.	2	4	9	8	8	—	—	—
9″ × 9″ × 4½″ angle blocks rebated for flues	4	16	12	12	8	—	—	See detail.
Chimney Pieces								
11″ × 2″ mantel shelf, rounded one edge	9 ft. (2 shelves)	27 ft. (6 shelves)	36 ft. (8 shelves)	12 ft. 6 in. (3 shelves)	9 ft. (2 shelves)	—	—	See details of chimney pieces
12″ × 2½″ do.	12 ft. (2 shelves)	12 ft. (2 shelves)	12 ft. (2 shelves)	6 ft. (1 shelf)	6 ft. (1 shelf)	—	—	Do.
3″ × 3″ × 9″ brackets	4	12	16	6	4	—	—	Do.
6″ × 3″ × 9″ do.	12	12	12	6	6	—	—	Do.
9″ × 3″ slab recessed on one edge to form fascia	4 ft. 6 in. (2 slabs)	13 ft. 6 in. (6 slabs)	18 ft. (8 slabs)	6 ft. 9 in. (3 slabs)	4 ft. 6 in. (2 slabs)	—	—	Do.
12″ × 4″ slab recessed on one edge to form fascia	9 ft. (2 slabs)	9 ft. (2 slabs)	9 ft. (2 slabs)	4 ft. 6 in. (1 slab)	4 ft. 6 in. (1 slab)	—	—	Do.
9″ × 3″ slab recessed on one edge to form sides	15 ft. (4 slabs)	45 ft. (12 slabs)	60 ft. (16 slabs)	21 ft. 6 in. (6 slabs)	15 ft. (2 slabs)	—	—	Do.
12″ × 4″ do.	16 ft. (4 slabs)	16 ft. (4 slabs)	16 ft. (4 slabs)	8 ft. (2 slabs)	8 ft. (2 slabs)	—	—	Do.
Extra forming pateriæ on 9″ × 3″ slab	4	12	16	6	4	—	—	Do.
Floors								
4″ floors (float finish)	83 sq. yd.	94 sq. yd.	126 sq. yd.	114 sq. yd.	87 sq. yd.	20 sq. yd.	48 sq. yd.	At ground floor.
4″ do. at first-floor level, reinforced	88 sq. yd.	97 sq. yd.	136 sq. yd.	—	—	—	—	—
4″ concrete flat, laid to falls	92 sq. yd.	110 sq. yd.	136 sq. yd.	132 sq. yd.	94 sq. yd.	20 sq. yd.	48 sq. yd.	—
6″ do., projecting 18″ to form cornice	32 sq. yd.	34 sq. yd.	41 sq. yd.	43 sq. yd.	35 sq. yd.	15 sq. yd.	24 sq. yd.	See detail.
6″ concrete flat over bay windows	—	—	5½ sq. yd.	—	3 sq. yd.	—	—	See detail.

Forming 2″ × 1″ groove in concrete flat	126 ft.	134 ft.	185 ft.	169 ft.	140 ft.	61 ft.	93 ft.	—
4″ concrete threshold	—	—	—	—	—	3 sq. yd.	5 sq. yd.	—
6″ × 6″ beams, reinforced with three $\frac{3}{4}$″ bars and $\frac{1}{2}$″ × $\frac{1}{8}$″ stirrups, as detail	39 cu. ft. (153 lin. ft.)	45 cu. ft. (181 lin. ft.)	69′ 9″ cube (278′ 8″ lin.)	27 cu. ft. (108 lin. ft.)	17 cu. ft. (68 lin. ft.)	7 cu. ft. (27 lin. ft.)	22 cu. ft. (68′ 3″ lin.)	—
2″ concrete shelf 3′ 4″ long, 1′ 8″ wide, built in wall one side and two ends	2	2	2	1	1	—	—	In larders.
4″ concrete hood over front doors	22 sq. ft.	22 sq. ft.	22 sq. ft.	—	—	—	—	See detail.
4″ brackets, 2′ wide, 18″ long	2	2	2	—	—	—	—	See detail.
8″ × 8″ posts 7′ long, reinforced with four $\frac{1}{2}$″ bars with $\frac{1}{8}$″ links, 6″ pitch	—	—	—	4	—	—	—	Porches.
8″ × 8″ do. 9′ long, and do.	—	—	—	—	2	—	—	Do.
Form haunching at top	—	—	—	4	2	—	—	Do.
9″ × 6″ beams with three $\frac{3}{4}$″ bars, and $\frac{1}{2}$″ × $\frac{1}{8}$″ stirrups as detail	—	—	—	14 cu. ft. (34 lin. ft.)	3 cu. ft. (8 lin. ft.)	—	—	Do.
Core and parge flues	4	8	12	4	3	—	—	—
Provide and fix approved well fire and back	2	6	8	3	2	—	—	—
Do. grate, complete with boiler	2	2	2	1	1	—	—	In living-rooms.
STAIRS, ETC.								
Concrete steps	62′ 4″ cube (26 steps)	62′ 4″ cube (26 steps)	62′ 4″ cube (26 steps)	—	—	—	—	As detail.
Building in ends of 11″ × 9″ concrete stairs	52	52	52	—	—	—	—	—
11″ × 2″ string, reinforced with two $\frac{1}{2}$″ bars, with 2″ projection on bottom edge	—	—	18 lin. ft.	—	—	—	—	See plans.
5″ × 5″ reinforced post recessed to receive string	—	—	24′ 6″ lin.	—	—	—	—	Do.
4″ landing	—	—	151 sq. ft.	—	—	—	—	—
Rounded ends to bottom steps	—	—	4	—	—	—	—	—
2″ × 2″ wood cap to string and landing, and include plugs in concrete	—	—	31 lin. ft.	—	—	—	—	—
2″ × 1″ wooden balusters fixed	—	—	92 lin. ft.	—	—	—	—	—
3″ × 2″ handrail, including ramps and angles	28 lin. ft.	28 lin. ft.	31 lin. ft.	—	—	—	—	—
CARPENTER AND JOINER								
Use and waste on 1″ shuttering to beams	2$\frac{1}{2}$ sqrs. (12 beams)	3 sqrs. (18 beams)	4$\frac{1}{2}$ sqrs. (22 beams)	2$\frac{1}{2}$ sqrs. (9 beams)	2 sqrs. (6 beams)	$\frac{1}{2}$ sq.	1$\frac{1}{4}$ sqrs.	—
Do. on 1″ centering to floors and roofs, etc., including props	19 sqrs.	21$\frac{1}{2}$ sqrs.	30 sqrs.	15$\frac{3}{4}$ sqrs.	12 sqrs.	3$\frac{1}{4}$ sqrs.	6$\frac{1}{2}$ sqrs.	—
DOORS AND FINISHING								
1$\frac{1}{2}$″ ledged and braced doors; $\frac{3}{4}$″ framed ledges and braces, covered with $\frac{3}{4}$″ boarding	80 sq. ft. (6 doors)	58$\frac{1}{2}$ sq. ft. (4 doors)	61 sq. ft. (4 doors)	41 sq. ft. (3 doors)	32$\frac{1}{2}$ sq. ft. (2 doors)	—	—	—
1$\frac{1}{2}$″ four-panel double moulded doors	133 sq. ft. (8 doors)	148$\frac{1}{2}$ sq. ft. (8 doors)	176$\frac{1}{2}$ sq. ft. (10 doors)	—	—	—	—	—

QUANTITIES OF MATERIALS REQUIRED FOR DESIGNS—*continued*

Descriptions	Types							Remarks
	No. 1	No. 2	No. 3	No. 4	No. 5	Garages		
						No. 6 One car	No. 7 Two cars	
1½″ six-panel doors	105 sq. ft. (6 doors)	158¾ sq. ft. (10 doors)	177 sq. ft. (10 doors)	166 sq. ft. (10 doors)	132¾ sq. ft. (8 doors)	—	—	—
1¾″ two-panel moulded and square doors, top panels with bars and beads for glass	41 sq. ft. (2 doors)	41 sq. ft. (2 doors)	41 sq. ft. (2 doors)	—	—	—	—	Back doors.
1¾″ four-panel moulded and square doors, top panel with bars and beads for glass	41 sq. ft. (2 doors)	41 sq. ft. (2 doors)	41 sq. ft. (2 doors)	41 sq. ft. (2 doors)	41 sq. ft. (2 doors)	—	—	—
2½″ two-panel folded doors with rebated and beaded styles, top panel with bars and beads for glass, lower panels with 1″ board	—	—	—	—	—	60 sq. ft. (1 door)	120 sq. ft. (2 doors)	—
⅞″ wrot. linings	123 sq. ft. (16 doors)	92⅓ sq. ft. (18 doors)	149 sq. ft. (20 doors)	67 sq. ft. (10 doors)	54 sq. ft. (8 doors)	—	—	—
1″ × ½″ wrot. stops	261 lin. ft. (16 doors)	292 lin. ft. (18 doors)	329 lin. ft. (20 doors)	160 lin. ft. (10 doors)	128 lin. ft. (8 doors)	—	—	—
2″ × ¾″ wrot. architrave nailed to ground, plugged to walls, including mitres	606 lin. ft. (20 doors)	629 lin. ft. (22 doors)	751 lin. ft. (24 doors)	369 lin. ft. (12 doors)	302 lin. ft. (10 doors)	—	—	—
LINEN CUPBOARD								
2″ slab partition	10 sq. yd.	10 sq. yd.	10 sq. yd.	5 sq. yd.	5 sq. yd.	—	—	—
4″ × 3″ uprights and bearers for tank	58 lin. ft.	58 lin. ft.	58 lin. ft.	29 lin. ft.	29 lin. ft.	—	—	—
4½″ × 3″ rebated and rounded frame	44 lin. ft.	44 lin. ft.	44 lin. ft.	22 lin. ft.	22 lin. ft.	—	—	—
4½″ × 3″ twice rebated do.	10 lin. ft.	10 lin. ft.	10 lin. ft.	5 lin. ft.	5 lin. ft.	—	—	—
Shelf, 1½″ × 1″ slats on 2″ × 1″ bearers	10 sq. ft.	10 sq. ft.	10 sq. ft.	5 sq. ft.	5 sq. ft.	—	—	—
½″ tongued V-jointed matchboarded fronts	50 sq. ft.	50 sq. ft.	50 sq. ft.	25 sq. ft.	25 sq. ft.	—	—	—
Extra on doors in same, 2′ × 2′	2	2	2	1	1	—	—	—
Pair 10″ tee hinges	2	2	2	1	1	—	—	—
Cupboard turn	2	2	2	1	1	—	—	—
SUNDRIES								
9″ × 1″ wrot. shelves and bearers	76 lin. ft.	80 lin. ft.	134 lin. ft.	40 lin. ft.	36 lin. ft.	—	—	In larder.
1¼″ draining boards 2′ long, 1′ 8″ wide, on 3″ × 2″ wrot. bearers	2	2	2	1	1	—	—	—
IRONMONGER AND SMITH								
Pairs 3″ butts	6	8	8	5	4	—	—	—
Do. 3½″ butts	8	12	—	5	4	—	—	—

Do. 4″ butts	4	4	16	2	2	—	—	—
Do. 12″ tee hinges	2	—	—	—	—	—	—	—
Do. 14″ tee hinges	2	4	—	3	2	—	—	—
Do. 18″ tee hinges	2	—	4	—	—	—	—	—
Do. 36″ hook and band hinges	—	—	—	—	—	2	4	—
Norfolk latches	4	2	4	2	2	—	—	—
6″ bolts	2	2	—	1	1	—	—	—
8″ do.	8	8	8	4	4	—	—	—
12″ do.	—	—	—	—	—	2	4	—
Postal handles	2	2	2	1	1	—	—	—
Dead lock	2	2	4	2	1	—	—	—
Rimlock and furniture	16	14	22	11	9	—	—	—
Night latches and three keys	2	2	2	1	1	—	2	—
Dowels and holes to frame and steps	12	8	16	8	8	2	4	—
Hardwood plugs	18	18	24	15	12	—	—	—
Elm plugs	84	120	120	72	48	—	—	—
Picture rails $\frac{1}{2}$″ dia. tubing on brackets fixed to wall	251 lin. ft.	299 lin. ft.	599 lin. ft.	218 lin. ft.	173 lin. ft.	—	—	—
Wrot. iron fixed casements, etc., complete	4	2	20	4	2	2	2	Light pattern.
Do. opening lights with fasteners, etc.	24	38	32	19	13	2	2	Do.
Steel mesh	212 sq. yd.	241 sq. yd.	339 sq. yd.	174 sq. yd.	131 sq. yd.	36 sq. yd.	72 sq. yd.	Measured net.
2″ cast-iron rainwater pipe	—	—	9 lin. ft.	—	9 lin. ft.	—	—	To bays.
3″ cast-iron rainwater pipes	36 lin. ft. (2 stacks)	36 lin. ft. (2 stacks)	54 lin. ft. (3 stacks)	36 lin. ft. (4 stacks)	27 lin. ft. (3 stacks)	9 lin. ft. (1 stack)	18 lin. ft. (2 stacks)	—
Rainwater heads	2	2	3	4	3	1	2	—
C.I. shoes to 3″ pipe	2	2	3	4	3	1	2	—
Do. to 2″ pipe	—	—	1	—	1	—	—	—
Provide and fix gas boiler	2	2	2	1	1	—	—	—
Provide and fix brass thimble for 2″ pipe	—	—	2	—	1	—	—	—
Do. 3″ pipe	2	2	3	4	3	1	2	—
PLASTERER								
$\frac{1}{4}$″ plaster to walls and twice distemper	406 sq. yd.	445 sq. yd.	638 sq. yd.	261 sq. yd.	197 sq. yd.	—	—	—
$\frac{1}{4}$″ do. 4″ wide to door and window reveals	145$\frac{1}{2}$ lin. ft.	216 lin. ft.	243 lin. ft.	126$\frac{1}{4}$ lin. ft.	75 lin. ft.	—	—	—
Cement angles	211 lin. ft.	298 lin. ft.	417$\frac{1}{4}$ lin. ft.	167$\frac{2}{3}$ lin. ft.	125 lin. ft.	—	—	—
Two coats white on concrete on walls	95 sq. yd.	144 sq. yd.	90 sq. yd.	79 sq. yd.	63 sq. yd.	43 sq. yd.	66 sq. yd.	—
Do. underside floors, beams, and stairs	172 sq. yd.	239 sq. yd.	266 sq. yd.	114 sq. yd.	87 sq. yd.	21 sq. yd.	54 sq. yd.	—
PLUMBER								
Provide and fix pedestal w.c. with trap, seat, two-gallon flushing cistern and brackets, 1$\frac{1}{4}$″ flush pipe, chain, and all necessary joints	2	2	2	2	2	—	—	—
$\frac{3}{4}$″ lead overflow	3 lin. ft.	3 lin. ft.	3 lin. ft.	3 lin. ft.	3 lin. ft.	—	—	—
4″ C.I. soil pipe	—	—	18 lin. ft.	—	—	—	—	—
Junction	—	—	1	—	—	—	—	—
Copper wire bonnet	—	—	1	—	—	—	—	—
Provide and fix bath, 5′×1′ 11″, with two $\frac{1}{2}$″ taps, 1$\frac{1}{4}$″ waste, plug, chain, trap, 1$\frac{1}{4}$″ overflow, and all joints	2	2	2	1	1	—	—	—

QUANTITIES OF MATERIALS REQUIRED FOR DESIGNS—*continued*

Descriptions	Types							Remarks
	No. 1	No. 2	No. 3	No. 4	No. 5	Garages: No. 6 One car	Garages: No. 7 Two cars	
$1\frac{1}{2}$" lead waste pipes with bends, joints, and fixing	5 lin. ft.	5 lin. ft.	5 lin. ft.	4 lin. ft.	4 lin. ft.	—	—	—
$1\frac{1}{4}$" lead overflow, and do.	3 lin. ft.	3 lin. ft.	3 lin. ft.	3 lin. ft.	$1\frac{1}{2}$ lin. ft.	—	—	—
2" C.I. waste pipe, joints, and fixing	18 lin. ft.	18 lin. ft.	18 lin. ft.	—	—	—	—	—
Shoe	2	2	2	—	—	—	—	—
Rainwater head	2	2	2	—	—	—	—	—
Provide and fix lavatory basin and brackets, with two $\frac{1}{2}$" brass pillar taps	2	2	2	1	1	—	—	—
$1\frac{1}{4}$" lead waste with bends and joints	4 lin. ft.	4 lin. ft.	4 lin. ft.	2 lin. ft.	2 lin. ft.	—	—	—
$1\frac{1}{4}$" lead traps and brass cleansing cap	2	2	2	1	1	—	—	—
$\frac{3}{4}$" bent lead overflow pipe, 12" girth	2	2	2	1	1	—	—	—
Provide and fix sink, overflow, etc., on brackets	2	2	2	1	1	—	—	—
$\frac{1}{2}$" lead water pipe and fixing hooks	120 lin. ft.	130 lin. ft.	150 lin. ft.	75 lin. ft.	65 lin. ft.	—	—	—
Provide and fix 40-gallon cisterns and valves	2	2	2	1	1	—	—	—
$\frac{3}{4}$" lead overflow	14 lin. ft.	14 lin. ft.	14 lin. ft.	11 lin. ft.	8 lin. ft.	—	—	—
One $\frac{1}{2}$" screw-down stopcock	2	2	2	1	1	—	—	—
$\frac{3}{4}$" galvanized steam piping	30 lin. ft.	44 lin. ft.	32 lin. ft.	19 lin. ft.	16 lin. ft.	—	—	—
Provide and fix 30-gallon tanks with bolted manhole	2	2	2	1	1	—	—	—
$1\frac{1}{4}$" galvanized flow and return pipes	140 lin. ft.	120 lin. ft.	96 lin. ft.	34 lin. ft.	20 lin. ft.	—	—	—
$\frac{1}{2}$" do.	60 lin. ft.	72 lin. ft.	84 lin. ft.	28 lin. ft.	17 lin. ft.	—	—	—
GLAZIER AND PAINTER								
21 oz. sheet glass and glazing	178 sq. ft.	266 sq. ft.	317 sq. ft.	139 sq. ft.	79 sq. ft.	15 sq. ft.	15 sq. ft.	In small squares.
Obscured glass and do.	25 sq. ft.	40 sq. ft.	$52\frac{1}{2}$ sq. ft.	33 sq. ft.	33 sq. ft.	—	—	Do.
Prepare and paint three coats on 3" pipes	14 lin. yd.	12 lin. yd.	21 lin. yd.	12 lin. yd.	9 lin. yd.	3 lin. yd.	6 lin. yd.	—
Do. 2" cast-iron pipes	6 lin. yd.	9 lin. yd.	9 lin. yd.	—	3 lin. yd.	—	—	—
Do. heads	4	4	5	4	3	1	2	—
Prepare and paint two coats, picture rail	84 lin. yd.	100 lin. yd.	200 lin. yd.	73 lin. yd.	58 lin. yd.	—	—	—
Prepare and paint three coats on steel casements both sides	28	40	52	23	15	4	4	—
Knot, prime, stop, and paint three oils on woodwork	143 sq. yd.	162 sq. yd.	188 sq. yd.	94 sq. yd.	79 sq. yd.	15 sq. yd.	30 sq. yd.	—
Total floor area in square feet	767	946	1,160	1,140	805	173	432	—
Contents in cubic feet	9,542	11,598	14,210	15,722	12,216	2,700	6,215	—

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